

REPORT

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Groundwater geochemistry of Rocky Flats Plant

# Groundwater Geochemistry of Rocky Flats Plant

December 16, 1993

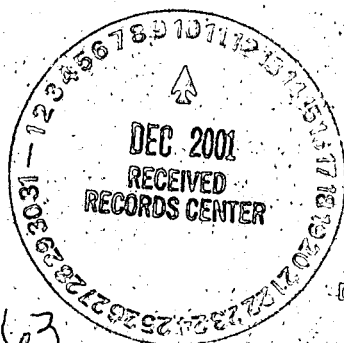


**ROCKY FLATS**

EG&G Rocky Flats, Inc.

P.O. Box 464

Golden, Colorado 80402



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# Groundwater Geochemistry of Rocky Flats Plant

December 16, 1993



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## **1.0 GEOLOGIC AND HYDROLOGIC SETTING**

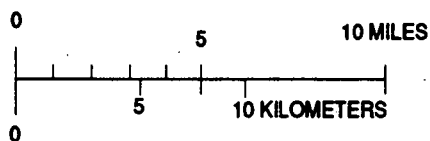
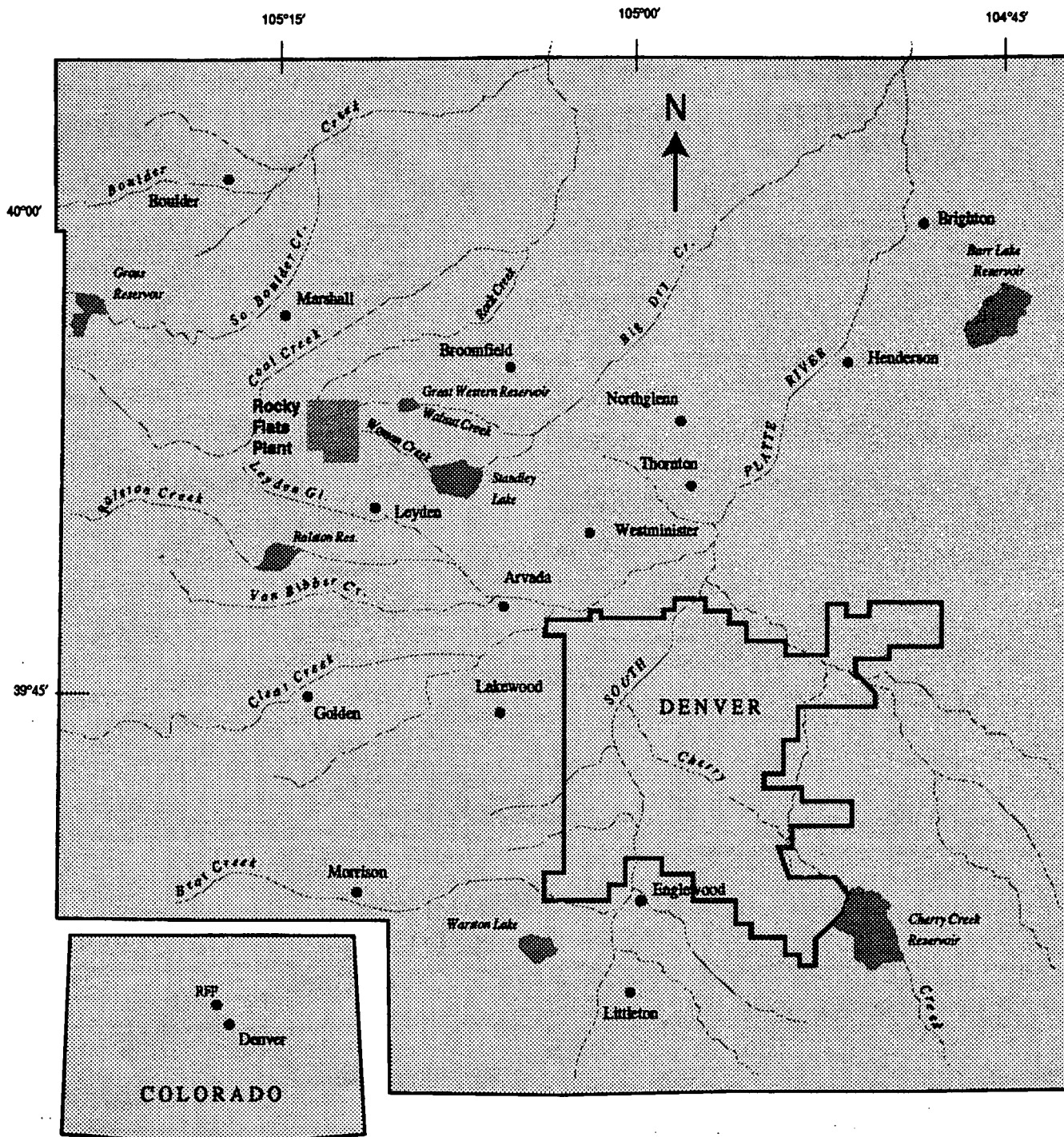
The Rocky Flats Plant (RFP) is a government-owned, contractor-operated facility under the direction of the U.S. Department of Energy (DOE). The RFP is currently in transition from a nuclear-defense production facility to one whose mission includes environmental restoration, waste management, and eventual decontamination and decommissioning.


RFP is situated at the eastern edge of the Colorado Front Range of the Southern Rocky Mountain province. It is located in Jefferson County, Colorado, approximately 16 miles northwest of downtown Denver (Figure 1.0-1). The plant site encompasses approximately 6,550 acres of federally owned land. The industrial area covers approximately 400 acres at the center of the plant site (Figure 1.0-2).

From 1951 to 1992, RFP manufactured metal components for nuclear weapons from plutonium, uranium, beryllium, and stainless steel. Other production activities included chemical recovery and purification of recyclable transuranic radionuclides, metal fabrication and assembly, and related quality-control functions. The plant also conducted research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics.

Solid and liquid nonhazardous, hazardous, radioactive, and mixed radioactive wastes were generated in RFP manufacturing processes and operations. Current waste-handling practices involve onsite storage of hazardous and solid radioactive wastes. In the past, disposal of hazardous and radioactive wastes has occurred on the site. The preliminary environmental assessment performed under the Environmental Restoration Program characterized wastes generated at the site and identified locations of past onsite storage and potential environmental contamination. Ongoing environmental restoration programs are further characterizing contaminant sources, release mechanisms, and fate and transport in the environment.

The purpose of this document is to utilize existing information and data to provide a description of the site physical features that influence groundwater flow and contaminant transport. To this end, the meteorologic, geomorphic, geologic, and hydrologic features of the site are described. Descriptions of the interactions between groundwater and geologic media



|   |              |
|---|--------------|
|  <b>ROCKY FLATS</b><br>Rocky Flats Plant, Golden, Colorado |              |
| <b>Location of Rocky Flats Plant</b><br>Groundwater Geochemistry of Rocky Flats Plant   |              |
| Date: December 1993   | Figure 1.0-1 |

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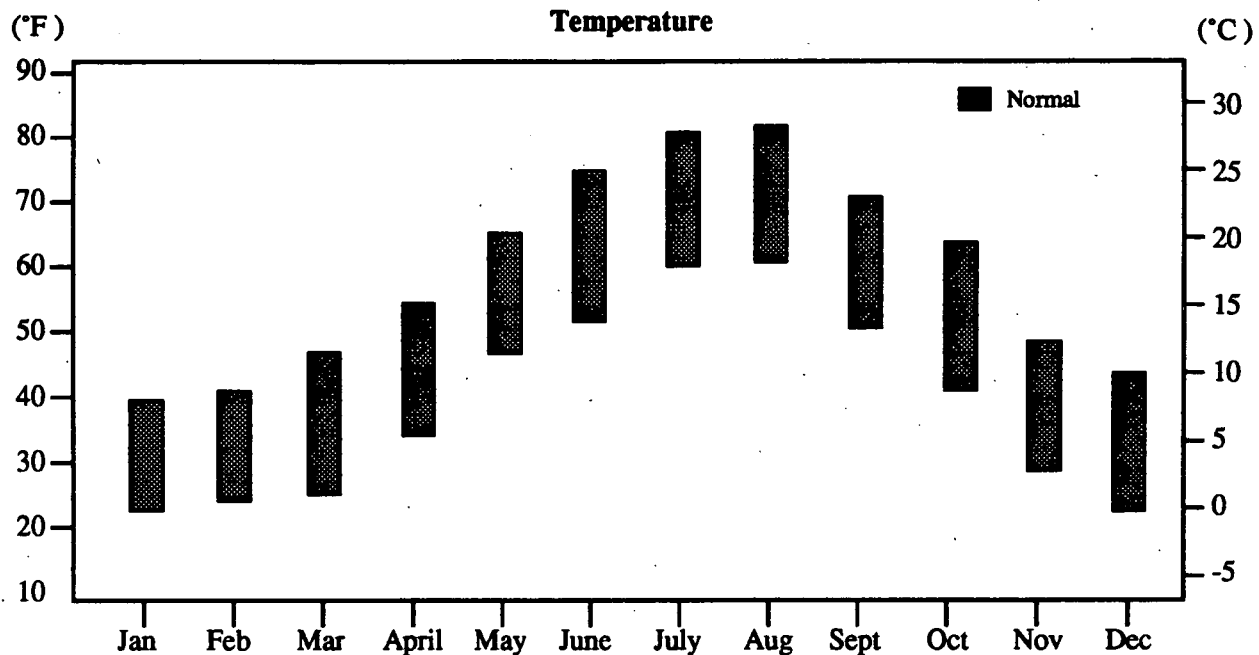
and between groundwater and surface water are also included, as these interactions can influence the fate and transport of groundwater contaminants.

### **1.1 Meteorology and Climate**

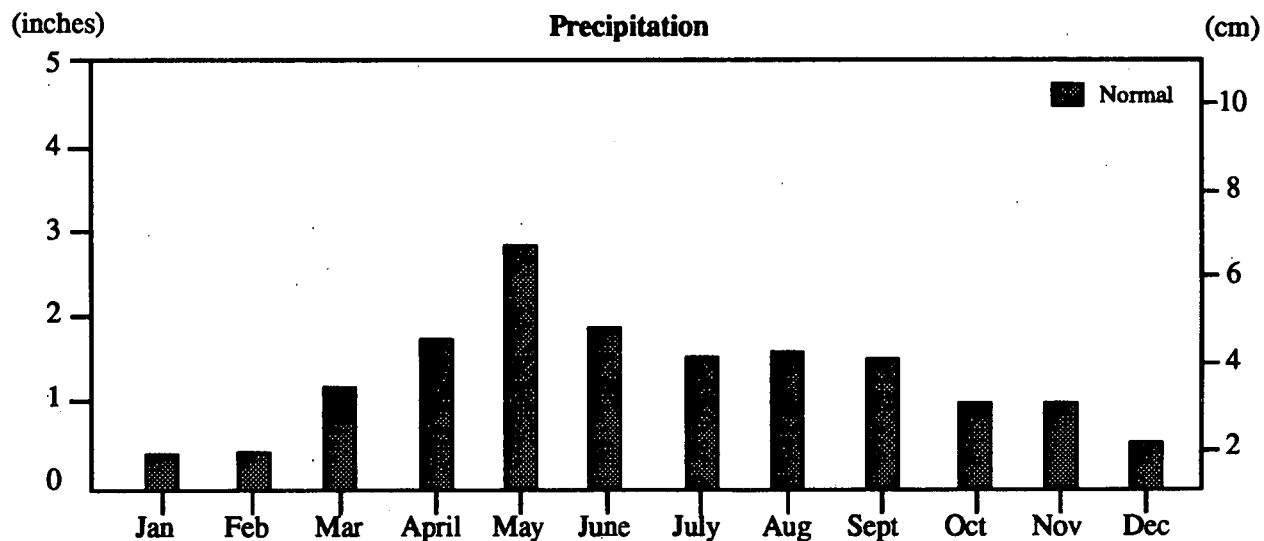
The area surrounding RFP has a continental, semiarid climate characteristic of the Southern Rocky Mountain region. Temperatures at RFP exhibit large seasonal variations and, occasionally, dramatic short-term changes. Summer high temperatures are typically in the mid-80°F range during the days with lows below 60°F at night. During the winter months, temperatures are relatively mild, ranging from 40 to 45°F during the day and from 15 to 25°F at night. Periods of extremely hot or cold weather are usually brief and do not occur every year. Temperature extremes recorded at the plant range from 102°F on July 12, 1971, to -26°F on January 12, 1963 (DOE, 1980). Figure 1.1-1 presents a summary of average, monthly temperature ranges.

Mean annual precipitation at RFP, including rainfall and snowmelt, is nearly 16 inches. Approximately 42 percent of the annual precipitation falls during the months of April, May, and June. Summer thunderstorms (July and August) account for an additional 30 percent of the annual precipitation. Autumn and winter are drier seasons, accounting for 19 and 11 percent of the annual precipitation, respectively. Snowfall averages 85 inches per year, occurring generally from October through May. Heaviest snowfall occurs in March. Snowfall provides approximately half of the total moisture for the year. The average relative humidity is 46 percent (DOE, 1980). Figure 1.1-1 presents a summary of average, monthly precipitation totals.

The plant site is noted for its strong, gusty winds, which frequently occur with thunderstorms and passage of weather fronts. The highest wind speeds, however, occur as westerly windstorms known as "chinooks." These winds occur during the period from late November into April, and the height of the season is in January. Chinook wind speeds typically exceed 75 miles per hour, and gusts may exceed 100 miles per hour. However, northwesterly wind directions and wind speeds under 15 miles per hour are the predominant wind conditions at RFP. Moderately strong northerly or southerly winds are common in winter and summer,



**Rocky Flats Plant Average Monthly Temperature Ranges**



**Rocky Flats Plant Average Monthly Precipitation**

**EB&B ROCKY FLATS**  
Rocky Flats Plant, Golden, Colorado

**Average Monthly Temperature  
Range and Precipitation**

Groundwater Geochemistry of Rocky Flats Plant

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Figure 1.1-1

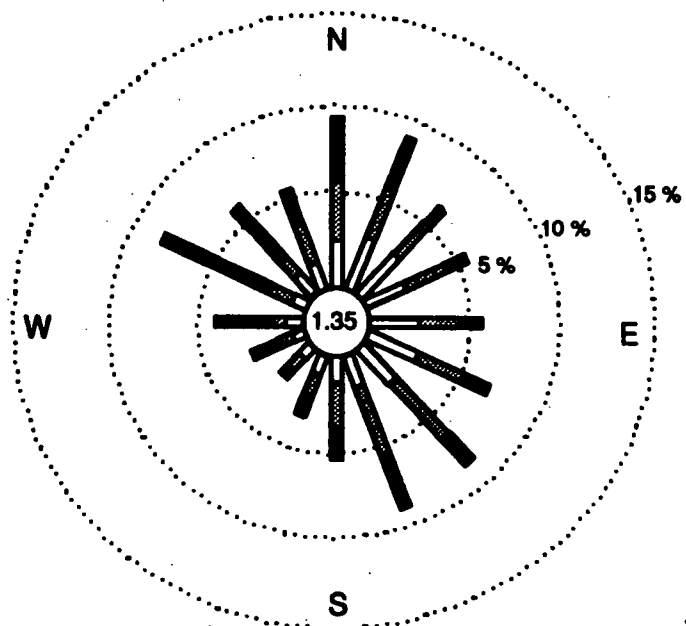
respectively, and easterly winds ("upslopes") may be associated with snowfall. The steep-sided canyons along the Front Range tend to channel the airflow during both upslope and downslope conditions (DOE, 1980).

RFP meteorology is strongly influenced by the diurnal cycle of mountain and valley breezes. Two dominant flow patterns exist, one during daytime conditions and one at night. During daytime hours, as the earth heats, air tends to flow toward the higher elevations (upslope). The general airflow pattern during upslope conditions for the Denver area is typically north to south, with flow moving up the South Platte River Valley and then entering canyons into the Front Range. After sunset, the air against the mountain sides is cooled and begins to flow toward the lower elevations (downslope). During downslope conditions, air flows down the canyons of the Front Range onto the plains. This flow converges with the South Platte River Valley flow moving toward the north-northeast (Hodgin, 1983 and 1984; DOE, 1986). A summary of 1992 wind direction and speed is illustrated in Figure 1.1-2 in the form of wind-rose diagrams. The diurnal pattern of wind directions is evident on these diagrams.

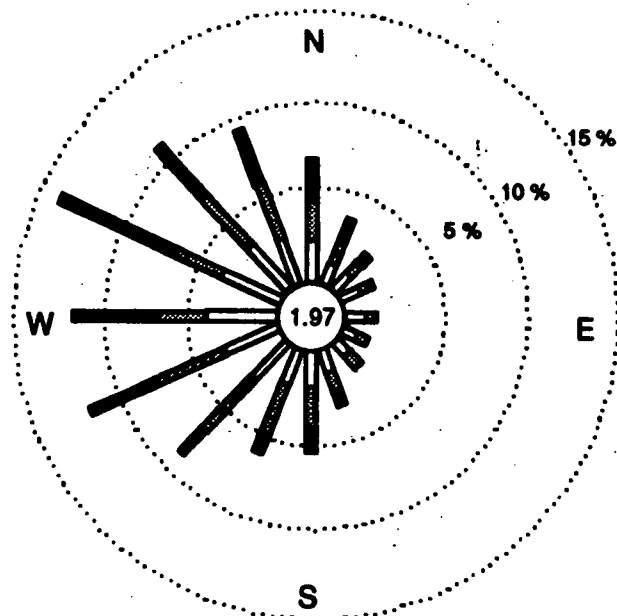
## **1.2 Surface Features**

One of the most significant features at RFP, relative to groundwater and surface-water flow, is the surface topography or geomorphology (Figure 1.0-2). RFP is located on a broad, eastward sloping plain just east of the Colorado Front Range. The surface cover is composed of a series of coalescing alluvial fans that were developed along the Front Range during the Pleistocene. The alluvial fans extend eastward approximately 5 miles from their origin near the mouth of Coal Creek Canyon. The industrial area at RFP is located near the eastern extent of the alluvial-fan deposits.

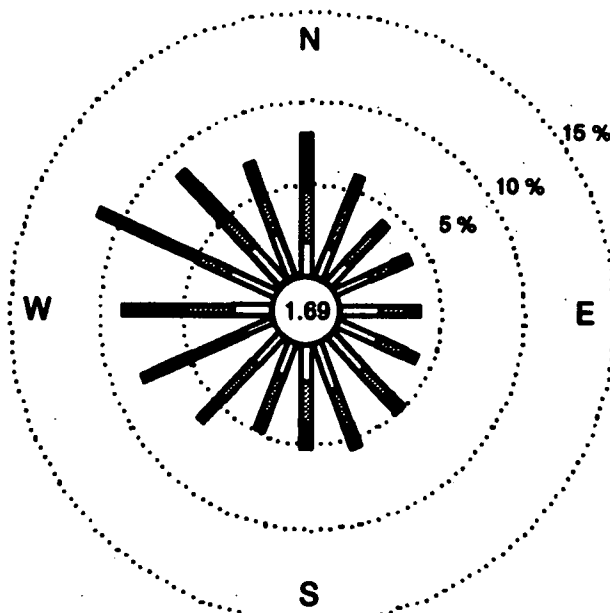
The alluvial fans were deposited on a broad, gently sloping erosional surface, or pediment. This gravel-capped pediment surface has been locally dissected and reworked by headward erosion and planation along several eastward-flowing intermittent streams and their tributaries, including Rock Creek, Walnut Creek, and Woman Creek. Fluvial processes have formed moderately steep hill slopes adjacent to the stream drainages, with the steepest slopes formed along the tops of the incised drainages. The industrial area of RFP occupies a topographic high between two such incised drainages, Walnut Creek to the north and Woman Creek to the south (Figure 1.0-2).



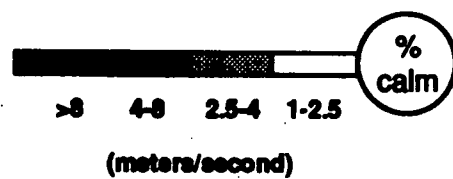
1992 Day



1992 Night



1992 Total



**ROCKY FLATS**  
Rocky Flats Plant, Golden, Colorado

**1992 Wind-Rose Diagrams**  
for the Rocky Flats Plant  
Groundwater Geochemistry of Rocky Flats Plant

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Figure 1.1-2

### **1.3 Geologic Setting**

The geology of RFP and the surrounding area (Figure 1.3-1) strongly influences the movement of groundwater, surface water, and potential contaminants. The following section focuses on the regional tectonic setting and lithologic and structural characteristics of the geologic units at RFP. The primary sources of information used to compile this description are existing geologic characterization reports (EG&G, 1991a, 1992a), U.S. Geological Survey publications (Spencer, 1961; Van Horn, 1957, 1972), and Colorado School of Mines reports (Weimer, 1976).

#### **1.3.1 Regional Tectonic Setting**

RFP is situated on a broad, eastward-sloping pediment surface. This surface is underlain by more than 10,000 feet of gently dipping (less than 2 degrees) Pennsylvanian to Upper Cretaceous sedimentary rocks in the Denver Basin. West of RFP, these strata are abruptly upturned along the western limb of the Denver Basin and form hogback ridges parallel to the Front Range uplift (Figure 1.3-2). At RFP, the slope of the pediment surface (approximately 6 degrees) is steeper than the dip of the underlying sedimentary rocks (approximately 1 to 2 degrees). As a result, shallow upper-cretaceous strata pinch out to the east against the erosion surface rather than plunging down into the subsurface toward the center of the Denver Basin.

#### **1.3.2 Stratigraphy**

Geologic units that influence groundwater flow include Quaternary deposits of unconsolidated surficial materials and Cretaceous bedrock. A generalized stratigraphic section for RFP shows the vertical sequence of surficial deposits and bedrock (Figure 1.3-3). These geologic units are described below using descriptions of lithologic characteristics from the Phase II Geologic Characterization Report (EG&G, 1992a).

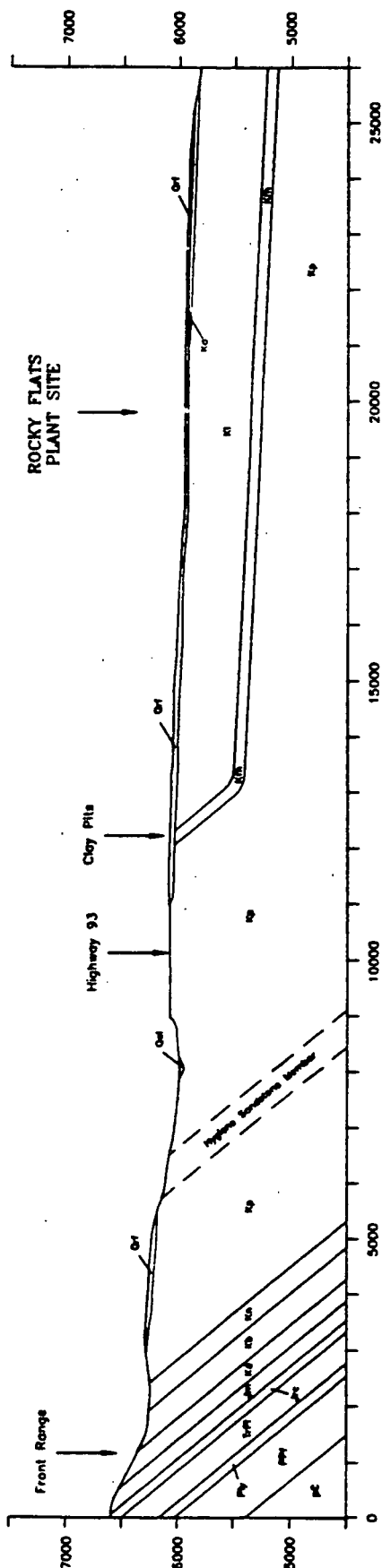
##### **1.3.2.1 Unconsolidated Surficial Deposits**

Unconsolidated surficial deposits consist of Quaternary Rocky Flats Alluvium, younger undifferentiated alluvium, colluvium, valley-fill alluvium, landslide deposits, and artificial fill. All surficial deposits except colluvium are shown on the geologic map (Figure 1.3-1).



WEST

EAST



# EXPLANATION

- Qr1 = Quaternary Rocky Flats Alluvium
- Qd1 = Quaternary Valley Fill Alluvium
- Kd = Cretaceous Arapahoe Formation
- Kf = Cretaceous Fox Hills Sandstone
- Kp = Cretaceous Pierre Shale
- Kn = Cretaceous Niobrara Formation
- Kb = Cretaceous Benton Shale
- Jm = Jurassic Morrison Formation
- Jrc = Jurassic Reliance Creek Formation
- Tri1 = Permian-Liasak Lykins Formation
- Py = Permian Lyons Sandstone
- Pp1 = Pennsylvanian-Permian Fountain Formation
- PC = Precambrian

After EG&G (1992c)



Rocky Flats Plant, Golden, Colorado

Generalized East-West Cross-Section,  
Front Range to Rocky Flats

Groundwater Geochemistry of Rocky Flats Plant

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Figure 1.3-2

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| Age        | Formation                       | Thickness (feet)        |
|------------|---------------------------------|-------------------------|
| Quaternary | Rocky Flats Alluvium/ Colluvium | 0-100                   |
| Cretaceous | Arapahoe Formation              | 0-50                    |
|            | Laramie Formation               | 600-800                 |
|            |                                 | upper interval: 300-500 |
|            |                                 | lower interval: 300     |
|            | Fox Hills Sandstone             | 90-140                  |
|            | Pierre Shale and older units    |                         |

**Clayey Sandy Gravels** – reddish brown to yellowish brown matrix, grayish-orange to dark gray, poorly sorted, angular to subrounded, cobbles, coarse gravels, coarse sands and gravelly clays: varying amounts of caliche

**Claystones, Silty Claystones, and Sandstones** – light to medium olive-gray with some dark olive-black claystone, silty claystone, and fine-grained sandstone, weathers yellowish orange to yellowish brown; a mappable, light to olive gray, medium- to coarse-grained, frosted sandstone to conglomeratic sandstone occurs locally at the base (Arapahoe marker bed)

**Claystones, Silty Claystones, Clayey Sandstones, and Sandstones** – kaolinitic, light to medium gray claystone and silty claystone and some dark gray to black carbonaceous claystone, thin (2') coal beds and thin discontinuous, very fine to medium-grained, moderately sorted sandstone intervals

**Sandstones, Claystones, and Coals** – light to medium gray, fine- to coarse-grained, moderately to well sorted, silty, immature quartzose sandstone with numerous claystones, and subbituminous coal beds and seams that range from 2' to 8' thick

**Sandstones** – grayish orange to light gray, calcareous, fine-grained, subrounded glauconitic, friable sandstone

Reference: Phase II Geologic Characterization  
Surface Geologic Mapping Report, March 1992

**EG&G ROCKY FLATS**  
Rocky Flats Plant, Golden, Colorado

**Generalized Stratigraphic Section  
for the Rocky Flats Plant**

Groundwater Geochemistry of Rocky Flats Plant

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Figure 1.3-3

### *Artificial Fill*

Artificial fill and disturbed surficial material are present at several Individual Hazardous Substance Sites, at the earthen dams for the A-, B-, and C-series ponds, at the Present Landfill, and along the surface-water diversion ditches at RFP.

### *Landslide Deposits*

Landslide deposits develop by downslope, mass movement of geologic materials on oversteepened valley slopes and along the banks of creeks and ponds. Slumps are commonly present on hillslopes composed of claystones of the upper Laramie and Arapahoe Formations. They are characterized by a curved scarp at the top, a coherent mass of material downslope that may be rotated back toward the slip plane, and hummocky topography at the base. Areas of creep are expressed in weakly consolidated, grass-covered slopes as bulges or low, wavelike swells.

### *Valley-Fill Alluvium*

Quaternary valley-fill alluvium of the Louviers, Broadway, pre-Piney Creek, Piney Creek, and post-Piney Creek Alluvium consists of channel and terrace deposits in and along Rock Creek, Walnut Creek, and Woman Creek. Valley-fill deposits consist of light brown to gray, humic clay, silt, and sand with lenses of gravel. Gravels have a silt matrix that is generally iron stained. Deposits of valley-fill alluvium are variable in age and range from 0 to 25 feet in thickness.

### *Colluvium*

Quaternary colluvium mantles the valley slopes between the pediment on which the Rocky Flats Alluvium is deposited and the Rock Creek, Walnut Creek, and Woman Creek drainages. Colluvial material was deposited by slope wash and downward creep of alluvial material and bedrock. The colluvium consists of moderate to dark brown, structureless clay with some sand and gravel. Colluvial deposits range from 0 to 20 feet in thickness; deposits are thinnest on the steep portions of valley slopes and thickest near the drainages at slope bottoms (EG&G, 1993b). Note that colluvial deposits are not shown on Figure 1.3-1, which is primarily a

bedrock geologic map. Across the plant site, colluvium covers most of the bedrock shown in Figure 1.3-1.

#### *Younger Undifferentiated Alluvium*

Undifferentiated alluvial deposits of the Verdos and Slocum Alluvium are present on pediments topographically below the pediment surface on which the Rocky Flats Alluvium was deposited, but above the channel and terrace deposits of Walnut Creek and Woman Creek. These undifferentiated alluvial deposits consist of light to moderate brown, clayey, coarse gravel and coarse sand and range in thickness from 10 to 50 feet.

#### *Rocky Flats Alluvium*

The Rocky Flats Alluvium comprises a series of coalescing alluvial fans. The alluvium ranges from 1 to 100 feet in thickness and is thickest west of RFP near the apex of the fans and thinnest east of RFP near the depositional limit of the fans (EG&G, 1992a). The Rocky Flats Alluvium consists of yellowish brown to reddish brown, poorly sorted, coarse bouldery gravel in a silt and clay matrix with lenses of clay, silt and sand, and varying amounts of caliche. Generally, the gravels are coarser grained west of RFP and become finer grained toward the east. Pebbles, cobbles, and boulders are composed primarily of quartzite but include lesser amounts of schist, gneiss, granite, pegmatite, sandstone, and siltstone.

#### 1.3.2.2 Bedrock Units

Bedrock unconformably underlies the surficial deposits and consists of claystones, siltstones, and sandstones of the Upper Cretaceous Arapahoe Formation, Laramie Formation, and Fox Hills Sandstone (Figure 1.3-3). The topography of the bedrock surface has been scoured and shaped by various alluvial and fluvial processes. Bedrock highs are generally present between the Rock Creek, Walnut Creek, and Woman Creek drainages. Weathering of bedrock is dependent on factors such as the abundance of fractures, presence of root zones, elevation relative to the water table, and proximity to drainages and appears to be most extensive along the drainages.

### *Arapahoe Formation*

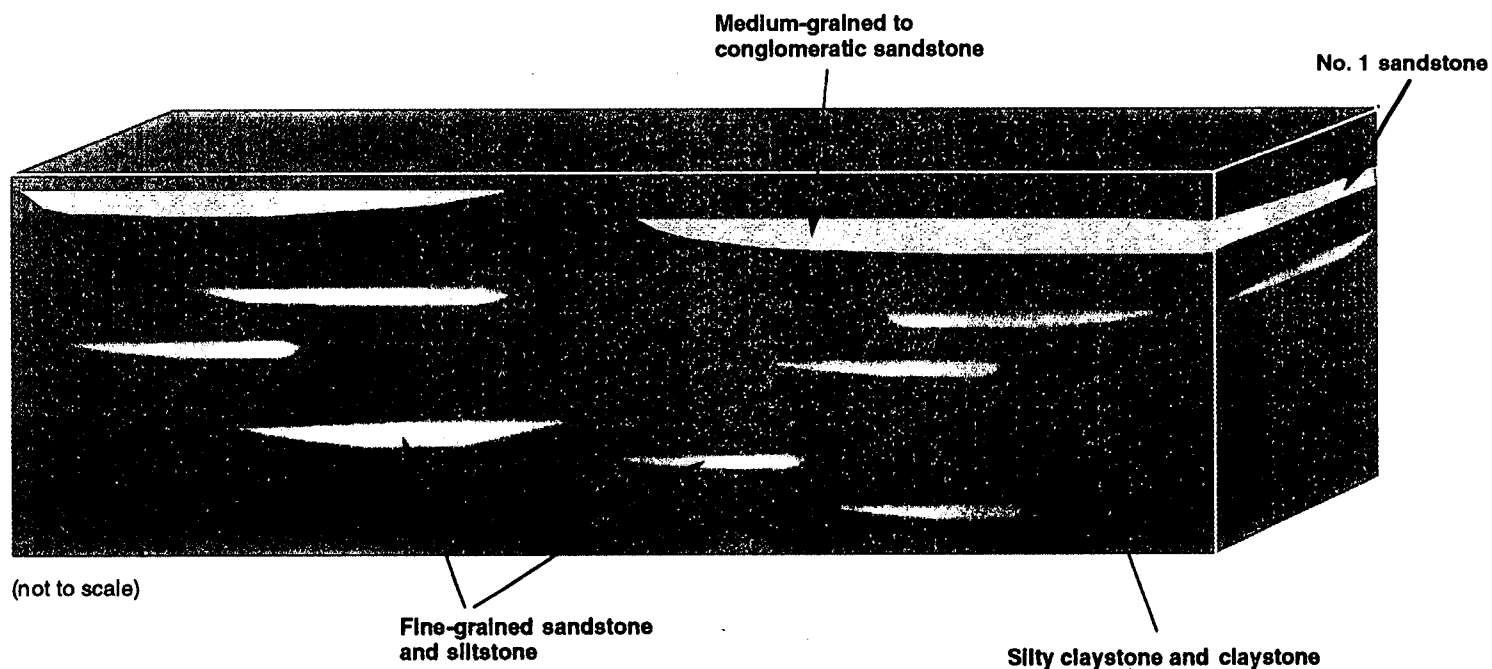
The Upper Cretaceous Arapahoe Formation, as defined in the Phase I Geologic Characterization Report (EG&G, 1991a), is approximately 150 feet thick beneath the middle portion of RFP. It contains at least five separate, discontinuous, but mappable sandstone units, designated as the Number (No.) 1 through No. 5 sandstones. More recent work, based on field mapping (EG&G, 1992a), indicates that the Arapahoe Formation is less than 50 feet thick in the middle portion of RFP. The basal Arapahoe sandstone, as defined in the Phase II Geologic Characterization Surface Geologic Mapping Report (EG&G, 1992a), is stratigraphically equivalent to the uppermost, or No. 1, sandstone of the Phase I Geologic Characterization Report. Attempts to resolve this controversy are in progress. Regardless of the thickness described for the Arapahoe Formation at RFP, the No. 1 sandstone is the uppermost sandstone unit of significant lateral extent, and it is of concern as a potential migration pathway.

The No. 1 sandstone is a yellowish-gray to dark yellowish-orange, fine- to medium-grained, locally conglomeratic, subangular to subrounded, moderately to poorly sorted, planar-laminated to trough cross-bedded sandstone, with an abundance of grains of well-rounded quartz sand. Conglomeratic sandstone lenses at the base of the unit contain pebbles of chert, ironstone, and rock fragments (EG&G, 1992a; Van Horn, 1972; Weimer, 1976). Subcrops of the No. 1 sandstone are present on the bedrock high between South Walnut Creek and Woman Creek, where the sandstone is in hydraulic connection with the overlying Rocky Flats Alluvium. At some locations, the No. 1 sandstone fills channel forms that lie atop claystones of the Laramie Formation (Figure 1.3-4).




### *Laramie Formation*

The Upper Cretaceous Laramie Formation unconformably underlies the Arapahoe Formation and is approximately 600 to 800 feet thick. The Laramie Formation is informally subdivided into two members; the upper member is generally much finer grained than the lower member.

The upper member of the Laramie Formation is approximately 300 to 500 feet thick and consists primarily of olive-gray and yellowish-orange claystones. Four sandstone units (designated as the No. 2, No. 3, No. 4, and No. 5 sandstones) have been identified in the bedrock beneath the No. 1 sandstone and are in the Arapahoe Formation, as defined in the



**Key:**

-  Number 1 sandstone
-  Number 2,3,4,5 sandstones
-  Silty claystone, siltstone, and claystone of Laramie and Arapahoe Formations

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Rocky Flats Plant, Golden, Colorado

**Schematic Diagram Showing Sandstones in  
the Arapahoe and Laramie Formations**  
Groundwater Geochemistry of Rocky Flats Plant

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Figure 1.3-4

Phase I Geologic Characterization Report (EG&G, 1991a) or in the Laramie Formation, as defined in the Phase II Geologic Characterization Report (EG&G, 1992a) and shown in this report (Figures 1.3-3 and 1.3-4). Deep boreholes, drilled during the 1991-1992 sitewide geologic-characterization program and targeting these sandstones, encountered siltstone more often than sandstone. Where present the sandstones are olive gray, very fine-grained, subangular, well-sorted, platy-laminated to ripple-laminated, locally calcareous, silty, and clayey. Because they lie within claystones and they are not in hydraulic connection with either the No. 1 sandstone or the surficial deposits, the No. 2 through 5 sandstones are probably not significant migration pathways for potential contaminants to groundwater.

The lower member of the Laramie Formation is 300 feet thick and is composed of sandstones, claystones, and coal beds. The sandstones are yellowish gray, very fine- to medium-grained, subangular to subrounded, moderately sorted, thin- to thick-bedded, ripple-laminated to trough cross-bedded, and contain abundant plant remains. These sandstone beds are more laterally extensive than sandstone beds in the upper Laramie Formation. Claystones present within the lower Laramie Formation are generally kaolinitic.

### *Fox Hills Sandstone*

The Upper Cretaceous Fox Hills Sandstone ranges from 90 to 140 feet in thickness and conformably underlies the Laramie Formation. In general, the Fox Hills Sandstone is a very fine- to medium-grained, angular to subrounded, well-sorted, silty sandstone. Thin beds of siltstone and claystone are common, especially near the base of the formation where the Fox Hills Sandstone is interfingered with the underlying Pierre Shale (EG&G, 1992a). The Fox Hills Formation lies at a depth of 700 to 800 feet below ground surface at RFP.

### 1.3.3 Depositional Environments

Unconsolidated surficial materials were deposited by alluvial, fluvial, and geomorphic processes. The Rocky Flats Alluvium was deposited by an emerging mountain stream as a series of alluvial fans on the pediment east of the Front Range uplift. Younger undifferentiated alluvial deposits of the Verdos and Slocum Alluvium were deposited on lower pediments by a variety of alluvial processes. Valley-fill alluvium of the Louviers, Broadway, pre-Piney Creek, Piney Creek, and post-Piney Creek Alluvium was deposited by modern ephemeral

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streams. Colluvium was formed by slope wash and downward creep of alluvial material and shallow bedrock along steep valley slopes. Slump or landslide deposits were formed by the downslope transport of soil and rock material *en masse*.

The No. 1 sandstone has been interpreted as part of a fluvial fining-upward sequence, deposited as meandering channel, point bar, overbank, and crevasse splay deposits (EG&G, 1991a). Individual channel sandstones can become stacked by vertical aggradation, but most tend to be separated from each other by substantial amounts of claystone. The channel sandstones are characterized by lenticular, shoestring geometries. These factors tend to decrease hydraulic conductivity in the vertical dimension, and laterally, across the dip direction.

The Arapahoe or Laramie Formation No. 2, No. 3, No. 4, and No. 5 sandstones have been preliminarily interpreted as marine or marginal-marine, tidal channels and tidal flats (C. Dodge, 1993). These sandstones are thinner and more silt- and clay-rich than the No. 1 sandstone, display less lateral continuity, and do not exhibit depositional characteristics typically associated with channel sandstones (EG&G, 1991a, 1992a). Additional investigations on the depositional environments of these units are currently in progress.

#### 1.3.4 Structural Features

The folded structure of bedrock strata immediately west of RFP results in steeply eastward-dipping exposures of the Fox Hills Sandstone and Laramie Formation. These units receive recharge from precipitation along the exposed hogbacks northwest and southwest of RFP (see Figure 1.3-1). Other large-scale features that may significantly affect the direction and rate of groundwater flow are currently under investigation.

Small-scale structural features, such as joints and fractures, are present in bedrock units. Surfaces of joints and fractures are commonly coated with secondary oxide and hydroxide minerals in the weathered portion of bedrock units. Slickensides are also present on some fracture surfaces. The presence of such features increases secondary porosity and permeability and may facilitate groundwater transport through bedrock units by providing preferential flow paths in low-permeability claystones.



## **1.4 Hydrologic Setting**

An understanding of the site hydrological conditions and the mechanics of groundwater flow is critical to the identification of transport pathways for groundwater contaminants. The following section provides a description of the hydrologic setting of RFP in terms of both the surface-water and groundwater hydrology.

### **1.4.1 Surface-Water Hydrology**

The 1990 Surface Water and Sediment Geochemical Characterization Report (EG&G, 1992b) provides a detailed description of surface-water features at RFP. This section is primarily based on information provided in that report.

Natural drainage basins and ephemeral streams, diversion canals, ditches, and retention ponds all define surface-water flow at RFP. A generalized map of the principal drainage basins and other surface-water features shows that three intermittent streams drain the plant site and flow generally west to east (Figure 1.0-2). These drainages are known as Rock Creek, Walnut Creek, and Woman Creek. Flow in these drainages occurs mainly after precipitation events and during spring snowmelt. In addition to the natural drainages, there are numerous man-made controls on surface-water flow. The natural drainages, man-made ditches and diversions, and other engineered controls on surface-water flow are described below.

Rock Creek drains the northwestern portion of RFP and flows northeast through the buffer zone to its offsite confluence with Coal Creek. This drainage does not receive surface-water runoff from the industrial area of the plant site. This drainage is therefore considered to be unaffected by industrial activities at the plant, including potential contaminant releases to surface water. Within the plant boundaries, the Rock Creek drainage basin is approximately 2.9 square miles in area.

South Walnut Creek, North Walnut Creek, and an unnamed tributary flow together to form Walnut Creek. These major tributaries drain the central and northeastern area of the site, including the northernmost portion of the plant's industrial area. Most of the runoff from the industrial area is captured in detention ponds along the North Walnut Creek (A-series ponds) and South Walnut Creek (B-series ponds) tributaries. The three tributaries converge in the

buffer zone, approximately 0.7 miles west of the eastern boundary of RFP. From this confluence, the Walnut Creek drainage extends approximately 1 mile east to Great Western Reservoir. Flow from Walnut Creek is diverted around the Great Western Reservoir to Big Dry Creek via the Broomfield Diversion Canal, which is an offsite canal operated by the city of Broomfield. Within the plant boundaries, the drainage basin is approximately 3.6 square miles in area.

The Woman Creek drainage basin drains southern portions of the plant's buffer zone. An east-west trending interfluvial bisects the site and separates the Walnut Creek and Woman Creek drainages. Most of the flow within the Woman Creek drainage basin is controlled by a series of ditches. Surface runoff from the southern boundary of the plant's industrial area is collected in the parallel running South Interceptor Ditch (SID). The SID directs the water to a detention pond (Pond C-2) where water quality is monitored in accordance with RFP's National Pollutant Discharge Elimination System (NPDES) permit and eventually pumped to the treatment ponds (A-series ponds) in the Walnut Creek drainage basin. Surface runoff downstream of the SID enters Woman Creek and is directed to Mower Ditch, which delivers water to Mower Reservoir. The remaining water flows to Standley Lake. Standley Lake supplies water to the cities of Westminster, Northglenn, and Thornton. Within the plant boundaries, the Woman Creek drainage basin is approximately 3.1 square miles in area (DOE, 1992).

In addition to the natural stream drainages and the above-mentioned diversion channels, there are several other diversion ditches and canals in the vicinity of RFP. These ditches divert surface-water flow away from the industrial area of the plant. South Boulder Diversion Canal, located immediately outside the western boundary of the plant, carries water from South Boulder Creek to Ralston Reservoir, a water supply source for the city of Denver. The South Boulder Diversion Canal also supplies industrial and potable water to RFP.

A series of dams have been constructed to create detention ponds that capture surface runoff and discharges from the industrial area and control offsite releases of surface water. The ponds created directly downstream of the industrial area on North Walnut Creek are designated as the A-series ponds (A-1 through A-4). The B-series ponds (B-1 through B-5) are located downstream from the industrial area on South Walnut Creek. Pond B-3 also receives treated effluent from the onsite sewage-treatment plant. The C-series ponds are located along Woman Creek and capture runoff from the surrounding drainage basin. Pond C-2, located to the south

of Woman Creek, receives diverted flow from the SID and some runoff. The flow in Woman Creek is diverted to the north of and around Pond C-2. The water in Pond C-2 is monitored, treated, and eventually pumped to the Walnut Creek watershed, where it is released to the Broomfield Diversion Canal. The Landfill Pond, located to the east and downstream of the Present Landfill on the unnamed tributary of Walnut Creek, receives runoff from the surrounding drainage basin and seepage from the landfill. Water from the Landfill Pond is spray-evaporated in its immediate vicinity to maintain the pond's water level (DOE, 1991).

#### 1.4.2 Groundwater Hydrology

This section describes the groundwater flow systems and the types of groundwater/surface-water interactions at RFP and discusses a site-specific, conceptual model for groundwater flow. This description is based on existing documents, including the Groundwater Protection and Monitoring Program Plan (EG&G, 1991b), 1992 Background Geochemical Characterization Report (EG&G, 1992c), 1992 RCRA Groundwater Monitoring Report (EG&G, 1993a), Draft Final Phase III RFI/RI Report for Operable Unit 1 (DOE, 1992), and the Draft Final Well Evaluation Report (EG&G, 1993b).

Basic to the discussion of the site hydrogeology are the definitions of an aquifer, a lithostratigraphic unit, and a hydrostratigraphic unit. The following definitions will clarify discussions of the hydrologic setting at RFP. An aquifer is a saturated geologic unit (rock or unconsolidated deposit) capable of yielding an economic supply of water (Fetter, 1988; Freeze and Cherry, 1979). A geologic formation is a body of rock identifiable by lithic characteristics and stratigraphic position (Bates and Jackson, 1987). A formation may contain more than one lithostratigraphic unit, which is defined by its lithological characteristics. A hydrostratigraphic unit is composed of hydraulically connected geologic materials with similar hydrologic properties (i.e., hydraulic conductivity and porosity). A hydrostratigraphic unit may be composed of one or more lithostratigraphic units or geologic formations, and it may fit the definition of an aquifer or a confining layer.

The definition of a hydrostratigraphic unit currently in use at RFP is more general than that given above. The hydrostratigraphic units defined at RFP include lithostratigraphic units with a range of hydrologic properties (i.e., unconsolidated alluvial deposits and weathered claystone). All of the lithostratigraphic units within a hydrostratigraphic unit, however, are in

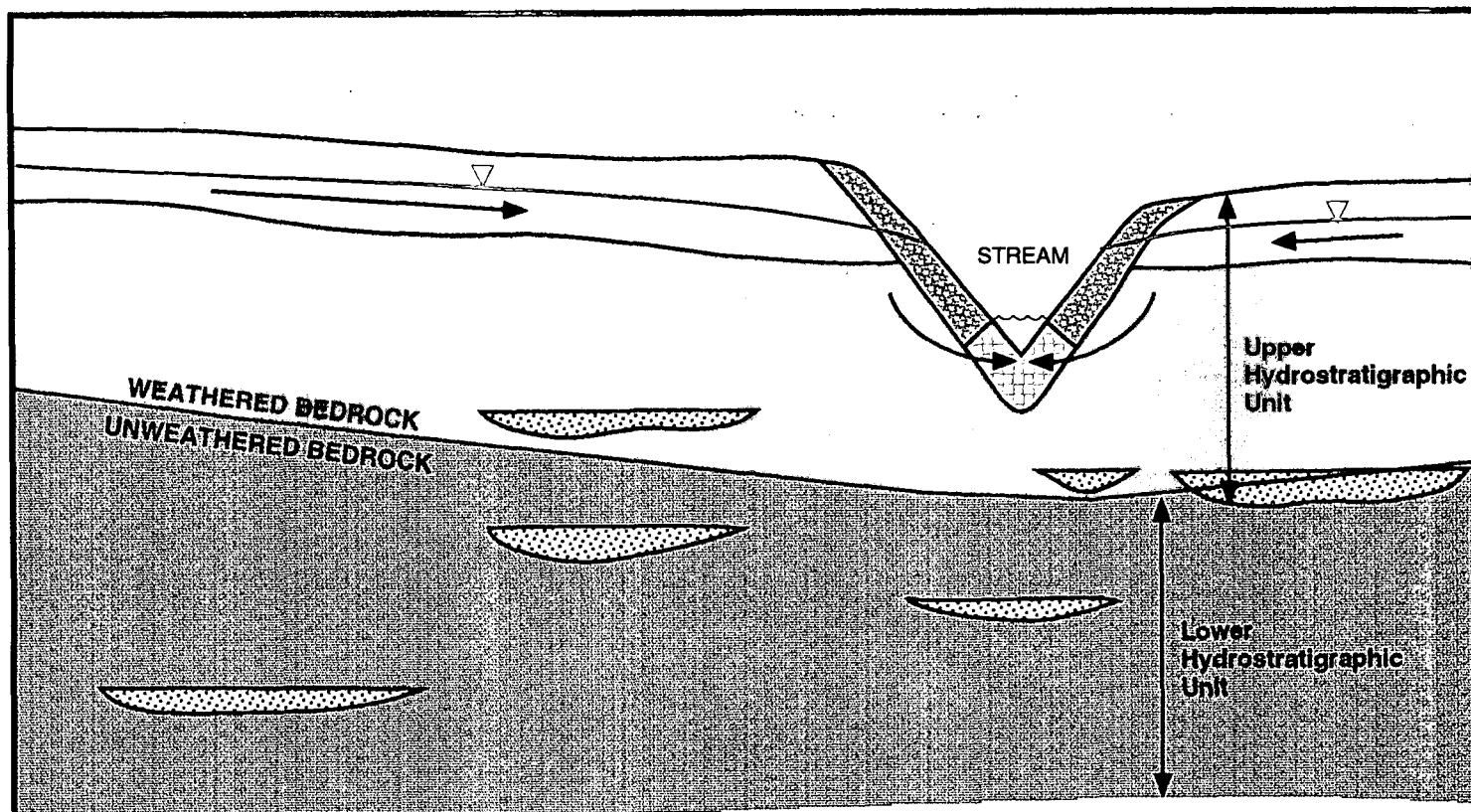
hydraulic connection with each other. Thus, for discussions of the RFP hydrologic setting, a hydrostratigraphic unit is defined as a group of lithostratigraphic units having roughly similar hydrologic properties and in hydraulic connection with each other.

#### 1.4.2.1 Hydrostratigraphic Units

At least two discernable hydrostratigraphic units are present at RFP. These are generally referred to as the upper hydrostratigraphic unit and the lower hydrostratigraphic unit (Figure 1.4-1). The upper hydrostratigraphic unit comprises several distinct lithostratigraphic units: Quaternary alluvium, colluvium, valley-fill alluvium, landslide deposits, weathered bedrock of the Arapahoe/Laramie Formation, and all sandstones within the Arapahoe and Laramie Formations that are in connection with overlying unconsolidated deposits or the ground surface (EG&G, 1991b). The lower hydrostratigraphic unit is composed mainly of unweathered bedrock of the Laramie Formation and includes unweathered portions of the Arapahoe Formation if present (EG&G, 1993b).

At RFP, groundwater is often classified by the lithostratigraphic unit it occupies. For example, the 1992 Background Geochemical Characterization Report (EG&G, 1992c) describes groundwaters associated with Rocky Flats Alluvium and valley-fill alluvium separately even though these waters occupy the same hydrostratigraphic unit. Groundwater monitoring wells at RFP are generally classified as either alluvial or bedrock with no distinction made between those screened in the upper and lower hydrostratigraphic units. This classification scheme is useful when describing detailed variations in groundwater chemistry but not as useful for discussions of groundwater flow.

The following description of the groundwater hydrology at RFP utilizes the hydrostratigraphic unit concept to discuss groundwater flow directions and the physical factors influencing contaminant transport.



**KEY:**

- Rocky Flats Alluvium
- Colluvium
- Valley Fill Alluvium
- Weathered Arapahoe/Laramie
- Unweathered Arapahoe/Laramie

- Sandstone
- Sandstone Lenses – separately comprise Lower Hydrostratigraphic Unit
- Flow
- Potentiometric Surface

Not to scale



Rocky Flats Plant, Golden, Colorado

**Hydrostratigraphic Units of Rocky Flats Plant**

Groundwater Geochemistry of Rocky Flats Plant

Date: December 1993

Figure 1.4-1

### *Upper Hydrostratigraphic Unit*

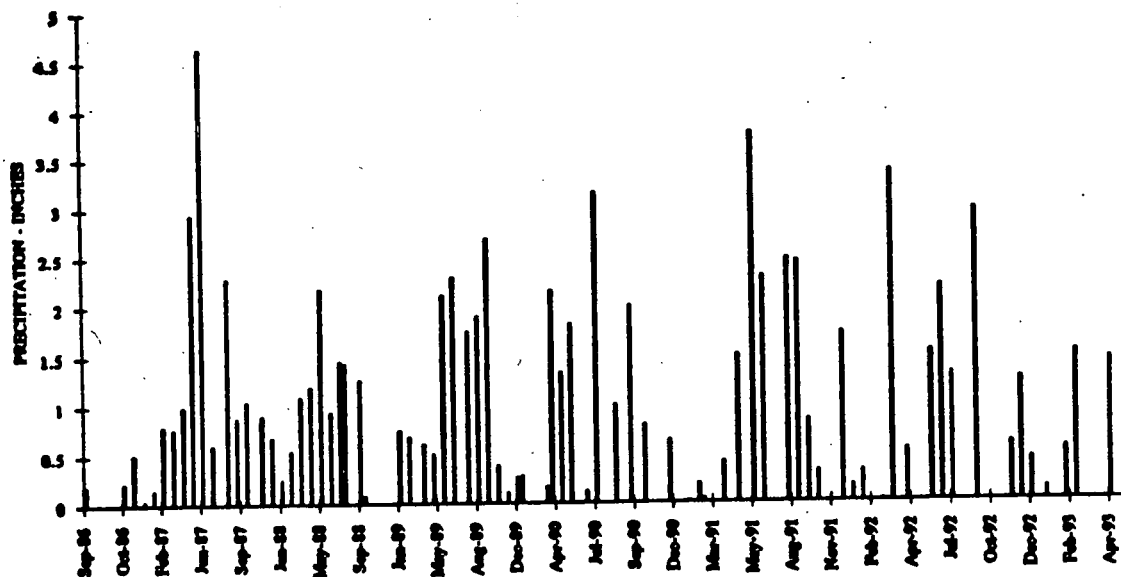
The upper hydrostratigraphic unit is the most laterally extensive water-bearing unit at RFP. Unconfined groundwater flows through this unit (EG&G, 1991b) and water levels rise and fall regularly in direct response to recharge and groundwater discharge. The thickness of the upper hydrostratigraphic unit is variable across the site and dependent upon the depth of weathered bedrock present. The weathered bedrock is commonly less than 15 feet thick but may extend to 60 feet below the top of bedrock (EG&G, 1993b). In areas where no weathered bedrock is present, the upper hydrostratigraphic unit consists only of unconsolidated surficial deposits. In general, the upper hydrostratigraphic unit ranges in thickness from 15 to more than 100 feet.

Recharge to the upper hydrostratigraphic unit results from infiltration of precipitation, storm runoff and snowmelt, and to a lesser extent, through seepage from streams, ponds, and ditches. The hydrographs in Figure 1.4-2 show variable water levels within the upper hydrostratigraphic unit through time. The seasonal response of water levels to periods of increased or decreased precipitation is evident when the well hydrographs are compared to precipitation records for the same time period (Figure 1.4-2).

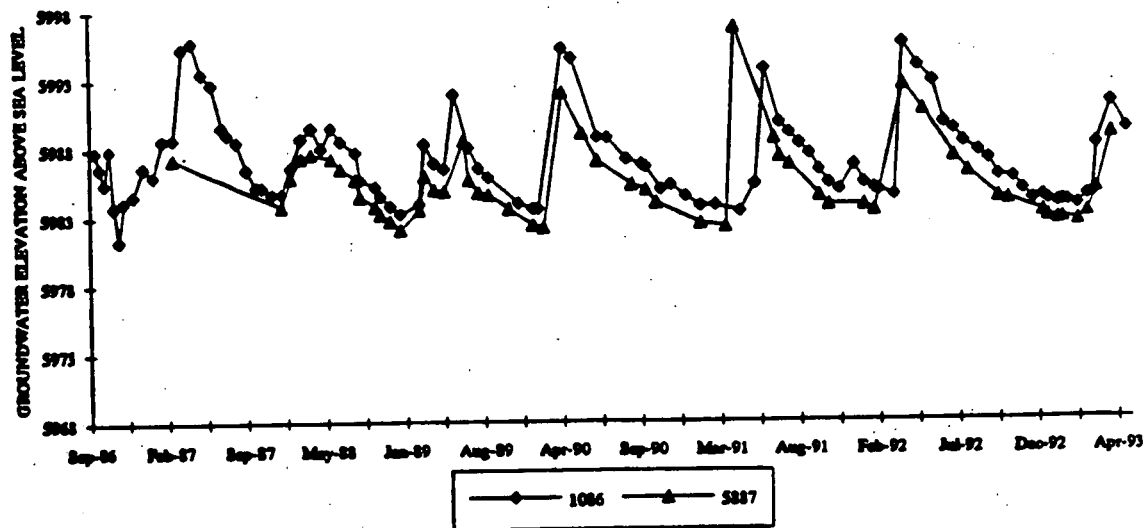
Groundwater is discharged from this unit by evaporation and evapotranspiration; through seeps; and also directly into streams, ditches, and ponds. Seeps are found along valley edges where the water table intersects the ground surface. Most seeps flow intermittently, usually during times of higher recharge when the water table is elevated. The water table rises to a maximum elevation during the wet season (April, May, and June) and generally declines during the remainder of the year. Seasonal fluctuations are most pronounced in the central portion of the plant where large areas of unsaturated Rocky Flats Alluvium develop during dry seasons (EG&G, 1993b). Unsaturated areas also occur where engineered structures have been installed to control groundwater flow at Operable Units 1 and 4 (DOE, 1992; EG&G, 1993a).

Groundwater in the upper hydrostratigraphic unit generally flows from west to east across the site. The direction of horizontal flow and the magnitudes of horizontal hydraulic gradients in the upper hydrostratigraphic unit are determined from potentiometric-surface maps. The potentiometric surface closely resembles the shape of the topographic surface (EG&G, 1993a and 1993b). The direction of groundwater flow is locally controlled by topographic highs and lows on the paleotopographic surface at the top of bedrock. Usually, the top-of-bedrock

### PRECIPITATION HYDROGRAPH



### WELL HYDROGRAPH



**ES&S ROCKY FLATS**  
Rocky Flats Plant, Golden, Colorado

#### Well Hydrographs

Groundwater Geochemistry of Rocky Flats Plant

Date: December 1993

Figure 1.4-2

surface closely reflects the shape of the ground surface. In some areas of the plant site, such as Operable Unit 2, data describing the subsurface are sufficient to reveal the presence of smaller scale ridges and valleys on the top of the bedrock surface (DOE, 1993). In these locations, the top-of-bedrock surface may provide channels that direct groundwater flow.

The rate of groundwater movement is controlled by the hydraulic gradient and the hydraulic conductivity of materials through which the water flows. The hydraulic conductivities of the unconsolidated Quaternary deposits differ by more than an order of magnitude from those of the weathered claystone and sandstone of the Arapahoe and Laramie Formations. On average, the unconsolidated Quaternary deposits have the highest hydraulic conductivities at RFP. The geometric means of hydraulic conductivities measured in Rocky Flats Alluvium and valley-fill alluvium range from approximately  $10^{-3}$  to  $10^{-4}$  cm/sec (B. Roberts, 1993). The weathered claystone and sandstone bedrock of the Arapahoe and Laramie Formations have hydraulic conductivities within a range from approximately  $10^{-5}$  to  $10^{-6}$  cm/sec (DOE, 1991 and 1992). As a result, groundwater flow is most rapid in the unconsolidated deposits of the upper hydrostratigraphic unit.

Water-level data from adjacent well pairs screened at distinct depth intervals within the upper hydrostratigraphic unit indicate that a downward-directed vertical gradient is most commonly present (see Figure 1.4-3). However, the degree of hydraulic connection between unconsolidated deposits and weathered bedrock varies (EG&G, 1993b). The contrast in hydraulic conductivities at the contact between these units impedes downward vertical flow and leads to predominantly lateral flow within the unconsolidated deposits along the top of the bedrock contact.

Along the axes of some creeks, vertical hydraulic gradients that are directed upward have been observed (Figure 1.4-3). Limited data indicate that in these areas groundwater in the bedrock may flow to unconsolidated deposits in the creek drainages (EG&G, 1993b). The amount and rate of upward flow to unconsolidated deposits will be controlled by the degree of hydraulic connection between bedrock and unconsolidated deposits.



### *Lower Hydrostratigraphic Unit*

The lower hydrostratigraphic unit is composed of all lithostratigraphic units in the unweathered portions of the Arapahoe and upper Laramie Formations except for subcropping sandstones (Figure 1.4-1). The lower hydrostratigraphic unit has been previously described as composed only of sandstone units within the unweathered portion of bedrock (EG&G, 1991b). In general, saturated sandstones that lie within unweathered claystones and siltstones of the Arapahoe or Laramie Formations are confined units. These sandstone units are not thought to be directly interconnected however, and each may act as an isolated hydrostratigraphic unit. In addition, recharge to these units occurs through the confining claystone and siltstone units. Therefore, all unweathered bedrock is considered part of the lower hydrostratigraphic unit (EG&G, 1993b).

Recharge to the lower hydrostratigraphic unit results by leakage from the saturated upper hydrostratigraphic unit. Limited discharge from the lower hydrostratigraphic unit occurs locally where the bedrock units intersect incised stream valleys. On a regional scale, the flow of groundwater in the lower hydrostratigraphic unit is from west to east. A sitewide potentiometric-surface map for the lower hydrostratigraphic unit has not been compiled. The degree to which individual sandstone units within the unit are interconnected is not known and an accurate potentiometric-surface map cannot be constructed from existing data.

The rate of groundwater flow is controlled by the hydraulic conductivity of the unweathered bedrock of the Arapahoe and upper Laramie Formations and the hydraulic gradient. The confining claystones of these formations are much less permeable than the stratigraphic units of the upper hydrostratigraphic unit, and they have the lowest hydraulic conductivities at RFP. Hydraulic conductivities of unweathered claystone at the RFP range from approximately  $10^{-6}$  to  $10^{-8}$  cm/sec (R. Smith, 1993; DOE, 1992). Relatively strong vertical hydraulic gradients within the lower hydrostratigraphic unit result in more rapid downward vertical flow than horizontal or lateral flow within that unit. However, vertical migration of groundwater into the lower hydrostratigraphic unit is impeded by the contrast in hydraulic conductivities at the contact between the upper and lower hydrostratigraphic units.

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*Laramie-Fox Hills Aquifer*

A regionally important aquifer known as the Laramie-Fox Hills aquifer (Robson, 1983) is present at greater depth below RFP. This deeper hydrostratigraphic unit is composed of the lower unit of the Laramie Formation and the underlying Fox Hills Sandstone. These units subcrop beneath the Rocky Flats Alluvium and are locally exposed in excavated gravel pits along the western boundary of the plant site. Recharge to the aquifer occurs along the Front Range. Claystones of the Laramie Formation have very low hydraulic conductivities; therefore, the U.S. Geological Survey (Hurr, 1976) has concluded that the plant operations will not impact this aquifer below the upper claystone units of the Laramie Formation.

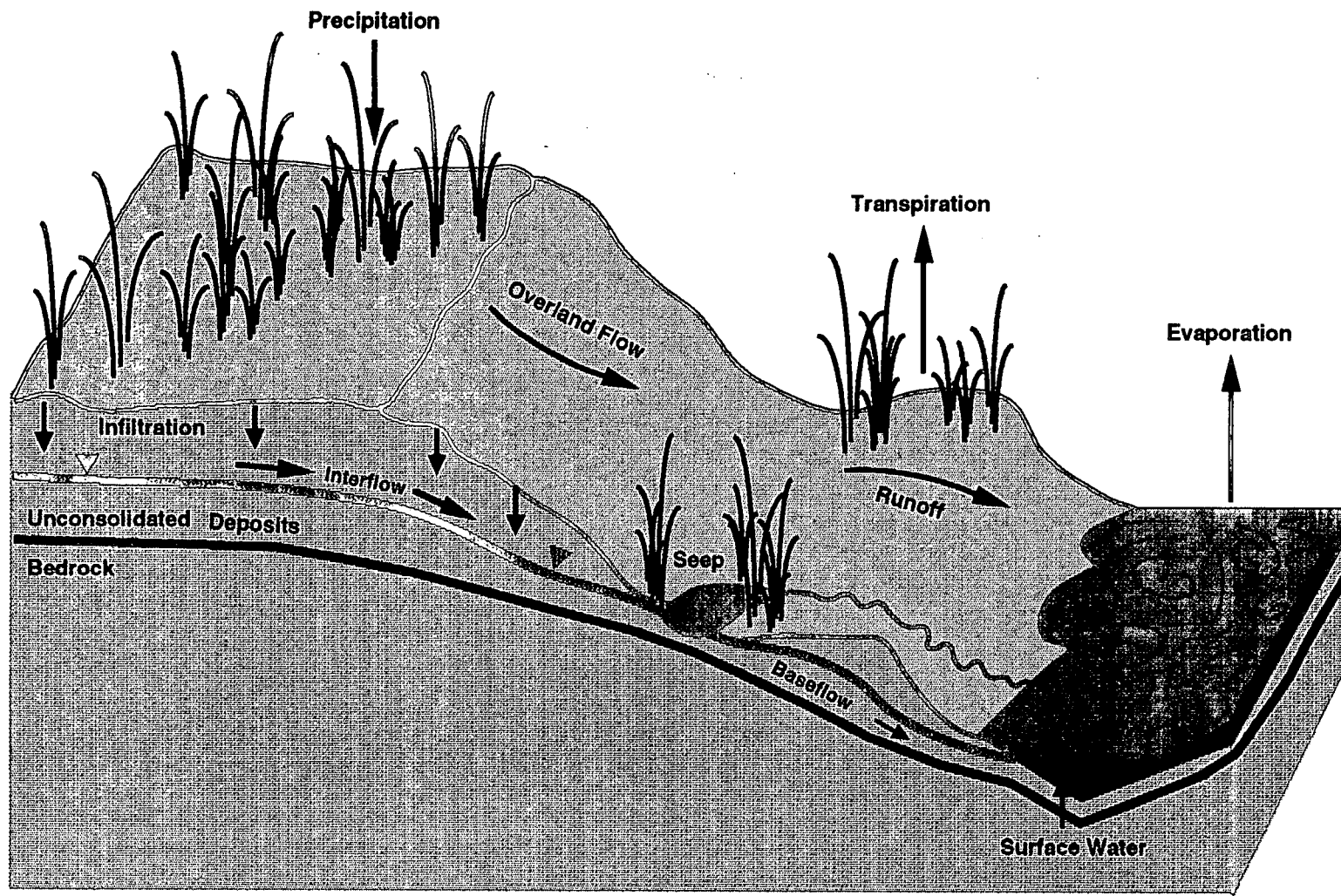
1.4.2.2 Groundwater/Surface-Water Interactions

In semiarid regions such as the location of RFP, surface-water bodies are fed by overland flow, interflow, and baseflow. Although precipitation and overland flow are major components in recharging surface water, interflow and baseflow can also be important. These two processes are discussed here as they relate directly to processes of recharge to and discharge from the upper hydrostratigraphic unit (Figure 1.4-4).

Interflow, also called subsurface stormflow (Freeze and Cherry, 1979), is lateral flow within the unsaturated zone. The primary condition required for interflow, a highly permeable zone at the ground surface, is often satisfied at RFP. In areas where permeable, unconsolidated deposits are present at the surface, precipitation or overland flow can infiltrate into the unsaturated zone. Interflow migrates downgradient and may recharge saturated materials in the upper hydrostratigraphic unit. In areas where the unconsolidated deposits remain entirely unsaturated, interflow is directed downslope along the top of the bedrock contact.

Baseflow is recharge to creeks from shallow groundwater. The amount of baseflow recharging creeks at RFP is related to the topography of the drainage basin. In areas with steep topography adjacent to creeks, there is potential for significant head differences between water-bearing geologic units and adjacent surface water. In areas along North and South Walnut Creeks and Woman Creek, the hydraulic head in the upper hydrostratigraphic unit is consistently higher than the head in the creeks or valley-fill alluvium. During wet seasons, the resultant hydraulic gradients cause baseflow recharge to the creeks (EG&G, 1993b).

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**EG&G ROCKY FLATS**

Rocky Flats Plant, Golden, Colorado

**Schematic Model for Surface  
Water/Groundwater Interactions**

Groundwater Geochemistry of Rocky Flats Plant

Date: December 1993

Figure 1.4-4

MES/RFP Schematic Model.mdw\12-15-93

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Groundwater also discharges from the upper hydrostratigraphic unit where the water table intersects the ground surface. Much of the groundwater in the unconsolidated surficial deposits may discharge at seeps or into colluvium. These discharges are most common along hillslopes at an elevation near the contact between the Rocky Flats Alluvium and bedrock. Seeps may also emerge where relatively permeable, saturated sandstone units subcrop. Water discharged at seeps re-infiltrates into colluvium or flows down hillslopes into valley-fill alluvium or creeks.

#### 1.4.2.3 Conceptual Model for Groundwater Flow

A conceptual model for unconfined groundwater flow (upper hydrostratigraphic unit) was developed for RFP as part of the Well Evaluation Report (EG&G, 1993b). Three general zones with distinct groundwater flow characteristics were identified and described. These zones trend north to south and occupy the western, central, and eastern portions of the plant site.

The western zone is characterized by a relatively unbroken topographic slope formed on the Rocky Flats Alluvium. In this zone, alluvial thicknesses are greatest, water-level fluctuations are minor, and the alluvium is rarely, if ever, completely unsaturated. Groundwater in the upper hydrostratigraphic unit flows generally east with slight variations in flow direction occurring along the top of the bedrock surface. The predominantly claystone bedrock impedes the downward vertical migration of groundwater and directs flow laterally.

The central zone has a gently eastward-sloping topographic surface that is incised by east-west-trending drainages. Topographic highs are capped by thick alluvial deposits and flanked by colluvium. Water flowing through the capping alluvium follows the bedrock surface and either emerges at seeps, drains into hillside colluvium, or migrates vertically into lower lithostratigraphic units (weathered or unweathered bedrock). The potentiometric surface of groundwater in the upper hydrostratigraphic unit generally mimics the ground surface and paleotopographic, bedrock surface. The potentiometric surface slopes gently to the east and more steeply north-northeast and south-southeast along hillslopes of the incised drainage valleys. Groundwater flows from broad areas of recharge located upgradient and on nearby topographic highs toward the erosional limit of alluvium and then directly toward creeks in incised drainages. Groundwater and surface water are in direct connection at seeps and in

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some alluvial deposits along these drainages. In areas of relatively steep topography, baseflow to creeks may occur. The paleotopographic bedrock surface also plays a role in directing groundwater flow and in the development of unsaturated zones in unconsolidated surficial deposits. Channels and depressions in the top-of-bedrock surface may act as conduits or even small basins for groundwater. Surficial deposits on either side of these channels can be drained, or dewatered, by flow toward the channel.

The eastern zone is characterized by relatively flat surface topography, the absence of thick alluvial deposits (Rocky Flats Alluvium), and more widespread valley-fill alluvial deposits. The ground surface is generally covered by thin deposits of colluvium. The hydraulic gradients are relatively low, and groundwater in unconsolidated surficial deposits may not flow directly toward the axes of stream valleys. Baseflow to creeks is probably also diminished relative to the central zone as a result of the lower hydraulic gradients.

## **2.0 ANALYSIS OF RESULTS FOR FIELD QUALITY-CONTROL SAMPLES**

A review and summary of chemical data collected as part of field quality-control sampling was performed to evaluate the quality and general usability of groundwater data collected for Rocky Flats groundwater monitoring programs. Chemical data for groundwater samples collected from 1986 through 1992 were obtained from the Rocky Flats Environmental Database System (RFEDS). The data assessed included results for dissolved and total metals, dissolved and total radionuclides, water-quality parameters (e.g., anions and cyanide), semivolatile acid/base/neutral (ABN) compounds, volatile organic compounds (VOCs), organochlorine pesticides and polychlorinated biphenyls (PCBs), and field measurements (e.g., dissolved oxygen and pH).

The data review included an assessment of the results reported for associated sample blank measurements (i.e., field, trip, and equipment-rinsate blanks). The data for field, trip, and equipment-rinsate blanks associated with these analytes may be used to determine whether contaminants detected in select samples are representative of in-ground conditions or are present due to contamination that occurred during sample collection or processing.

In addition, the relative percent difference (RPD) between results for original samples and field duplicates was calculated and reviewed. The data for field duplicates provide an estimate of sampling variability or precision and can be used to assess the quality of the monitoring data.

The procedures used for selecting data from the database, assessing results of specific chemical analyses, and evaluating the data quality are discussed in the following section (Section 1.1). Section 2.0 of the document provides details on the results of the quality-assurance review. A summary of overall data quality and general usability is provided in Section 3.0. Three appendices containing backup data on detected values, lists of analytes, and criteria for laboratory and validation qualifiers are also included.

### **2.1 Procedures for Assessing Data Quality**

The procedures used to evaluate data quality included a review of the summary of results reported for associated sample blank measurements, the RPDs of duplicate sample analyses, and the percentage of rejected data. The initial review of data for blank and duplicate samples revealed several inconsistencies associated with the RFEDS database. Generally, the inconsis-

tencies identified with the RFEDS database were 1) missing data for duplicate sample analyses, 2) different data qualifiers used for identical sample results entered for the same sample, 3) apparent anomalous results (e.g., outlier values exceeding other results by several orders of magnitude), 4) two results reported for the same sample, and 5) null entries for several analyte concentrations.

The inconsistencies and the subsequent actions taken to facilitate this review are summarized below:

**No matching duplicate data found:** For every data result identified as a duplicate there should exist a corresponding value for an original sample within the RFEDS database. In approximately 10 percent of all cases, a corresponding original value could not be found. Most of these cases occurred when the duplicate was not sampled on the same day as the original sample. Because field duplicates are intended to measure field and sampling variability and not temporal variability, these mismatched results were not used for this review. An archived data file containing a list of the duplicate results for which no matching original samples could be found is provided in Appendix A.

**Qualifiers differ for two results from the same sample:** In several instances, two results from the same sample were reported in the database, each with a different qualifier assigned to the same reported value. In cases where one result had a laboratory-assigned data qualifier and the other entry had only a data validation qualifier (i.e., verified by a third party), the original laboratory-qualified result was deleted and the laboratory qualifier was added to the validated result.

**Apparent outlier values reported:** Results that appeared to be anomalous (i.e., outliers) were not used for the purposes of this review when the result deviated an order of magnitude or more from the average result at the same sampling site for the analyte in question.

**Two results for same sample reported with different values:** When two results were reported for the same sample (same station or trip blank and date), it was not possible to determine whether the two results were associated with laboratory or field duplicates, sample dilutions, or sample reanalyses. For this review, the lowest value was ignored and only the greater value was used. The only exception to this amendment was for data reported for trip blanks for VOCs; all of these results were retained for review because multiple trip blanks are often associated with sample collection.

**Null entry reported:** In rare cases, a null entry (i.e., 0.00) was reported for an analyte and the entry was not used for interpretative purposes. The source of the null records within the database is unknown.

After the initial review of data, identification of inconsistencies, and completion of corrective actions listed above, all remaining detected results were subjected to a statistical analysis. Approximately 99 percent of the original field quality-control data were usable for this analysis; the remaining 1 percent of all data were rejected per the criteria stated above. The statistical analysis of the data included the identification of minimum, maximum, and average concentrations for all detected analytes, and calculation of the detection frequency.

Further data analysis included an evaluation of field-sampling precision and reproducibility of duplicate sample analyses. The precision of the data was evaluated by assessing the RPDs of detected duplicate sample analyses as follows:

$$RPD = \frac{C_1 - C_2}{(C_1 + C_2)/2} \times 100$$

where:

|       |   |   |
|-------|---|---|
| RPD   | = | relative percent difference             |
| $C_1$ | = | original sample analyte concentration   |
| $C_2$ | = | duplicate sample analyte concentration. |

The results of the data review summarized below are based on the amendments to the data set described above.



## **2.2 Review of Field Quality Control Samples**

### **2.2.1 Metals**

The specific metal analytes for which field duplicate and blank data were present are provided in Appendix B. Thirty-one of these metals and cyanide were detected in all associated sample blanks. The detected metals were typically reported at concentrations greater than the instrument detection limit (IDL), but less than U.S. Environmental Protection Agency (EPA) contract-required detection limit (CRDL). Such results are qualified (for inorganic analytes) with a laboratory or validation qualifier "B." For this review, metals were considered detected in accordance with the laboratory and validation qualifiers listed and defined in Appendix C. A summary of the results for all field-blank, trip-blank, and equipment-rinsate-blank measurements in the amended database is provided in Tables 2-1, 2-2, and 2-3, respectively. An archived data file containing a list of all blank samples that contained detected metals is provided in Appendix A.

The RPDs for all duplicate sample analyses identified in the database were calculated. RPDs exceeded EPA's Contract Laboratory Program (CLP) criterion of 20 percent for all analytes, with the exception of thallium, phosphorus, and silicon in selected duplicate sample analyses performed on dissolved fractions. Thallium and phosphorus had fewer duplicate samples on which to compute RPD compared to other analytes. Summary statistics of RPDs for the duplicate sample analyses are provided in Table 2-4. Matches between original and duplicate values were based on location, sample date, analytical group, and analyte. Appendix A provides a summary of duplicate sample results that could not be matched with corresponding original values (approximately 1 percent of the total number of duplicate observations in all years from 1986 through 1992).

The primary inconsistency identified during the assessment of metals data is that results reported at concentrations greater than the IDL, but less than the CRDL, were not consistently assigned a "B" concentration qualifier. This was especially true for data associated with samples collected during 1986 and 1987. In accordance with procedures established by EPA's CLP, the "B" concentration qualifier should be assigned when a target analyte is detected at concentration greater than the IDL and less than the CRDL.

2.2.1.1 Dissolved Metals

*Field Blanks*

A total of 7,073 analytical results were reported for the analyte metals. Of these results, 722 (10 percent) were reported as detected (primarily between the IDL and CRDL), 4,672 (66 percent) were reported as undetected at the IDL, and 1,679 (24 percent) were rejected. All rejected data are associated with field-blank measurements performed in 1986 (1,678 rejected) and 1989 (1 rejected). Of the data received for review, results for field blanks were reported for the period from 1986 to second quarter 1990. The highest detection frequencies were for aluminum, iron, sodium, and zinc.

*Trip Blanks*

A total of 5,677 analytical results were reported for the analyte metals. Of these results, 443 (8 percent) were reported as detected (primarily between the IDL and CRDL), 3,634 (64 percent) were reported as undetected at the IDL, and 1,600 (28 percent) were rejected. The rejected data are all associated with trip-blank analyses performed in 1986. Results for trip blanks were reported only for 1986–1989. No trip blank data collected after 1986 were rejected. The highest detection frequencies were for aluminum, calcium, iron, magnesium, and zinc.

*Equipment-Rinsate Blanks*

A total of 3,983 analytical results were reported for the analyte metals. Of these results, 797 (20 percent) were reported as detected (primarily between the IDL and CRDL), 3,155 (79 percent) were reported as undetected at the IDL, and 31 (less than 1 percent) were rejected. The rejected data are associated with all equipment-rinsate blank analyses performed in 1990, 1991, and 1992 (the only years in which equipment-rinsate blank data are reported). The highest detection frequencies were for aluminum, barium, calcium, iron, magnesium, manganese, silicon, sodium, strontium, and zinc.

#### 2.2.1.2 Total Metals

##### *Field Blanks*

A total of 206 analytical results were reported for the analyte metals. Of these results, 62 (30 percent) were reported as detected (primarily between the IDL and CRDL), 142 (69 percent) were reported as undetected at the IDL, and 2 (1 percent) were rejected. The rejected data are associated with field-blank measurements performed in 1990. Results for field blanks were reported only for 1990. The highest detection frequencies were for aluminum, barium, calcium, iron, magnesium, sodium, strontium, and zinc.

##### *Trip Blanks*

No total metals data for trip blanks were reported in the database.

##### *Equipment-Rinsate Blanks*

A total of 2,765 analytical results were reported for the analyte metals. Of these results, 457 (17 percent) were reported as detected (primarily between the IDL and CRDL), 2,274 (82 percent) were reported as undetected at the IDL, and 34 (1 percent) were rejected. The rejected data are associated with all equipment-rinsate blank analyses performed in 1991 and 1992. The highest detection frequencies were for aluminum, barium, calcium, magnesium, silicon, and sodium.

#### 2.2.2 Radionuclides

Analyses were performed for 21 radionuclide parameters, which are listed in Appendix B. For this review, all radionuclides were considered detected unless explicitly rejected in accordance with the laboratory and validation qualifiers listed and defined in Appendix C. A summary of the results for all field, trip, and equipment-rinsate blank measurements in the amended database is provided in Tables 2-5, 2-6, and 2-7, respectively. An archived data file containing a list of all blank samples that contained detected radionuclides is provided in Appendix A.

Table 2-8 summarizes RPD results for the radionuclide data. The RPDs calculated for duplicate radionuclide analyses indicate that sample analyses were not very reproducible. The RPDs ranged from 21 to 144 percent, with an average RPD of 66 percent. Appendix A provides a summary of duplicate sample results that could not be matched with corresponding original values. Matches between original and duplicate values were based on location, sample date, analytical group, and analyte.

#### 2.2.2.1 Dissolved Radionuclides

##### *Field Blanks*

A total of 1,172 analytical results were reported for radionuclides. Of these results, 785 (67 percent) were reported as detected and 387 (33 percent) were rejected. Results for field blanks were reported only for 1987–1990.

##### *Trip Blanks*

A total of 773 analytical results were reported for radionuclides. Of these results, 408 (53 percent) were reported as detected and 365 (47 percent) were rejected. Results for trip blanks were reported only for 1987–1989.

##### *Equipment-Rinsate Blanks*

A total of 1,047 analytical results were reported for radionuclides. Of these results, 987 (94 percent) were reported as detected and 60 (6 percent) were rejected. Results for equipment-rinsate blanks were reported only for 1990–1992.

#### 2.2.2.2 Total Radionuclides

##### *Field Blanks*

A total of 898 analytical results were reported for radionuclides. Of these results, 574 (64 percent) were reported as detected and 324 (36 percent) were rejected. Results for field blanks were reported only for 1986–1990.

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### *Trip Blanks*

A total of 517 analytical results were reported for radionuclides. Of these results, 166 (32 percent) were reported as detected and 351 (68 percent) were rejected. Results for trip blanks were reported only for 1986–1989.

### *Equipment-Rinsate Blanks*

A total of 608 analytical results were reported for radionuclides. Of these results, 563 (93 percent) were reported as detected and 45 (7 percent) were rejected. Results for equipment-rinsate blanks were reported only for 1990–1992.

## 2.2.3 Water-Quality Parameters

In general, target analytes (listed in Appendix B) associated with water-quality parameters (e.g., anions and cyanide) were undetected at concentrations above the method detection limit (MDL). A summary of the results for all field, trip, and equipment-rinsate blank measurements in the amended database is provided in Tables 2-9, 2-10, and 2-11, respectively. All blank samples that contained detectable concentrations of target analytes are summarized in data files included as Appendix A.

The RPDs for duplicate sample results were variable. There are no clearly established acceptance criteria for the precision of water-quality parameters. RPDs for carbonate, cyanide, oil and grease, pH, alkalinity, chemical oxygen demand, soluble fluoride, nitrate, silicon, sodium fluoride, and sodium sulfate were considered acceptable using a general criterion of 50 percent. A summary of duplicate sample results is provided in Table 2-12.

### 2.2.3.1 Field Blanks

A total of 1,259 analytical results were reported for the target water-quality parameters. Of these results, 291 (23 percent) were reported as detected at concentrations above the MDL, 949 (75 percent) were reported as undetected at the MDL, and 19 (2 percent) were rejected. Results for field blanks were reported only for 1986–1990.

#### 2.2.3.2 Trip Blanks

A total of 1,071 analytical results were reported for the target water-quality parameters. Of these results, 270 (25 percent) were reported as detected at concentrations above the MDL, 781 (75 percent) were reported as undetected at the MDL, and 20 (2 percent) were rejected. Results for trip blanks were reported only for 1986–1990.

#### 2.2.3.3 Equipment-Rinsate Blanks

A total of 1,376 analytical results were reported for the target water quality parameters. Of these results, 182 (13 percent) were reported as detected at concentrations above the MDL, 1,185 (86 percent) were reported as undetected at the MDL, and 9 (less than 1 percent) were rejected. Results for equipment-rinsate blanks were reported only for 1990–1992.

#### 2.2.4 Organic Compounds

The RFEDS data analyzed for this report contain results for 65 semivolatile ABN compounds, 69 VOCs, 23 organochlorine pesticides, and 7 PCBs. A data file containing a list of the target analytes associated with each of the three organic-compound groups is provided in Appendix B. For this review, results were considered detected in accordance with the laboratory and validation qualifiers listed in Appendix C. The results of the data review are summarized below.

##### 2.2.4.1 Semivolatile Acid/Base/Neutral Compounds

No semivolatile ABN compounds were detected in the field, trip, or equipment-rinsate blanks, with the exception of N-nitrosodiphenylamine in one field-blank sample. In addition, no analytes were detected in associated original samples at concentrations greater than the contract-required quantification limit (CRQL), with the exception of benzoic acid and bis(2-ethylhexyl)phthalate.

The RPDs for all duplicate sample results and precision cannot be adequately assessed because of the limited data set for detected analytes (two compounds). Of the two analytes detected,

however, RPDs of 11 and 109 (Table 2-13) were calculated. The RPD for bis(2-ethylhexyl)-phthalate exceeds the CLP criterion for precision.

#### *Field Blanks*

A total of 1,820 analytical results were reported for ABNs. Of these results, 1 (less than 1 percent) was reported as detected above the CRQL for N-nitrosodiphenylamine, 207 (11 percent) were reported as undetected at the CRQL, and 1,612 (89 percent) were rejected. Results for field blanks were reported only for 1986. All rejected data had a validation code of "N" and blank entries for reason codes. The interpretation of an "N" code is unknown.

#### *Trip Blanks*

A total of 1,820 analytical results were reported for ABNs. Of these results, none were reported as detected above the CRQL, 130 (7 percent) were reported as undetected at the CRQL, and 1,690 (93 percent) were rejected. Results for trip blanks were reported only for 1986. Rejected data had a validation code of "N" and blank entries for reason codes. The interpretation of an "N" code is unknown.

#### *Equipment-Rinsate Blanks*

A total of 3,250 analytical results were reported for ABNs. Of these results, none were reported as detected above the CRQL, 3,249 (greater than 99 percent) were reported as undetected at the CRQL, and 1 (less than 1 percent) was rejected. The result reported for benzoic acid in one equipment-rinsate blank from 1992 was rejected. Results for equipment-rinsate blanks were reported only for 1992.

#### 2.2.4.2 Volatile Organic Compounds

Several VOCs were detected in each type of blank sample. Typically, these detected analytes are associated with common laboratory contaminants (e.g., methylene chloride, acetone, and 2-butanone, which were consistently detected). Several of the other VOCs detected may be indicative of breakdown associated with the VOC absorbent trap. Caution should be used in determining whether a VOC detected in both a blank sample and any associated natural sample

is actually present. Specific assessment of this problem could not be performed during this review because detailed information (e.g., original laboratory data and field logs) was not available. A summary of the results for detected analytes in the associated blanks is provided in Tables 2-14, 2-15, and 2-16.

Although there are no specific criteria for determining acceptable RPDs for field duplicates established by EPA's CLP, several RPDs were very high, with maximum values ranging from up to 200 percent. Average RPDs were highest for bromodichloromethane and 1,2-dibromo-3-chloropropane (118 and 113 percent, respectively). The sample sizes for these two volatile organic compounds were low, however, and the high average RPDs may result from outlier values. Table 2-17 presents the RPDs for the VOC results.

#### *Field Blanks*

A total of 7,623 analytical results were reported for the target VOCs. Of these results, 256 (3 percent) were reported as detected above the CRQL, 6,904 (91 percent) were reported as undetected at the CRQL, and 463 (6 percent) were rejected. Results for field blanks were reported only for 1986-1990.

#### *Trip Blanks*

A total of 18,181 analytical results were reported for the target VOCs. Of these results, 573 (3 percent) were reported as detected above the CRQL, 16,934 (93 percent) were reported as undetected at the CRQL, and 674 (4 percent) were rejected. Results for trip blanks were reported only for 1986-1990.

#### *Equipment-Rinsate Blanks*

A total of 4,798 analytical results were reported for the target VOCs. Of these results, 131 (3 percent) were reported as detected above the CRQL, 4,542 (95 percent) were reported as undetected at the CRQL, and 125 (3 percent) were rejected. Results for equipment-rinsate blanks were reported only for 1990-1992.

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### 2.2.4.3 Organochlorine Pesticides and Polychlorinated Biphenyls

No target organochlorine pesticides and PCB compounds were detected in the field, trip, or equipment-rinsate blanks. In addition, no target analytes were detected in associated sample blanks at concentrations greater than the CRQL.

The RPDs for all duplicate sample analyses and the assessment of precision cannot be assessed because no target analytes were detected.

#### *Field Blanks*

A total of 806 analytical results were reported for the target organochlorine pesticides and PCBs. No compounds were reported as detected above the CRQL, 78 (10 percent) were reported as undetected at the CRQL, and 728 (90 percent) were rejected. Results for field blanks were reported only for 1986. All rejected data had a validation code of "N" and blank entries for reason codes. The interpretation of an "N" code is unknown.

#### *Trip Blanks*

A total of 780 analytical results were reported for the target organochlorine pesticides and PCBs. No compounds were reported as detected above the CRQL, 27 (3 percent) were reported as undetected at the CRQL, and 753 (97 percent) were rejected. Results for trip blanks were reported only for 1986. All rejected data had a validation code of "N" and blank entries for reason codes. The interpretation of an "N" code is unknown.

#### *Equipment-Rinsate Blanks*

A total of 184 analytical results were reported for the target organochlorine pesticides and PCBs. All 184 results were reported as undetected at the CRQL; no data were rejected. Results for equipment-rinsate blanks were reported only for 1992.

### 2.2.5 Field Measurements

Field measurement data could not be assessed. The results for a majority of the field measurements (alkalinity, dissolved oxygen, silica, specific conductance, and pH) were reported as null (0.00) entries in the database. Only eight values (two for dissolved oxygen, three for specific conductance, and three for pH) were reported at values greater than 0.00. A summary of the results in the database and the RPDs for duplicates of field measurements is provided in Tables 2-18 and 2-19, respectively.

### 2.3 Conclusions and Recommendations for Data Usability

During the quality-assurance review, several specific deficiencies were identified, some of which may result in specific limitations of data usability. The deficiencies or limitations identified with the data set are as follows:

- Results for accuracy (i.e., matrix spike recoveries) were not available for review and are not available from RFEDS. Without an assessment of accuracy measurements, the possible bias that may be associated with specific data cannot be evaluated.

- The frequency of metals detected in trip and field blanks is relatively high, with the most frequently detected analytes including aluminum, calcium, iron, magnesium, silicon, sodium, and zinc. Commercial-grade distilled water is used to prepare these blanks and is a likely source for the frequently detected metals. For this reason, analyses of these frequently detected metals in field blanks may not be useful in identifying field or laboratory contamination of real samples. The concentrations of most metals detected are lower than the EPA CRDL, suggesting that blank contamination by metals is not a serious problem.

- The RPDs for all duplicate analyses performed for metals, excluding silicon and the infrequently measured thallium and phosphorus, often exceeded the 20 percent RPD criterion for acceptable performance. For radionuclide analyses, RPDs were highly variable and typically high. Elevated RPDs are not unusual when analyte concentrations are at or near the detection limit (especially for

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metals). For radionuclides, elevated RPDs are associated with low radionuclide activities that are not within the range required to obtain reproducible results. Due to the low activities of natural waters at Rocky Flats and the poor laboratory precision associated with measuring these activities, analyses of duplicate samples for radionuclides does not provide a measure of sampling precision.

VOC analyses of trip or field blanks indicate that acetone, carbon disulfide, dichloromethane, and 2-butanone were typically present in the blanks. These compounds may originate from the commercial-grade distilled water used to prepare the blanks and they have also been identified as common laboratory contaminants (U.S. EPA 1988a). In accordance with procedures specified by EPA functional guidelines (U.S. EPA 1988a,b, 1990a), results for analytes detected in blanks may require restating results from associated real samples as undetected. This assessment should be performed during data validation. Until the results of such an assessment are available, the presence of acetone, carbon disulfide, dichloromethane, and 2-butanone in a field sample should be considered as potentially resulting from laboratory contamination. Results for this group of compounds should be qualified in RFEDS and further evaluated. At present, these results are considered usable as screening-level data.

Temporal trends in detection frequency of blanks and RPD values are not readily apparent. A consistent suite of quality-control-sample types apparently was not collected prior to 1990. In most cases, only 3 years of data are available to make comparisons, and the sample sizes in some of these years can be very low. There is a tendency, however, toward decreased detection of heavy metals and VOCs in rinsate blanks (Tables 2-4 and 2-16) for the period 1990-1992.

The data records reviewed for this analysis were obtained from RFEDS in 1993. Approximately 45 percent of the records in this data set have been reviewed and evaluated in accordance with the procedures required by EPA for documentation and validation of Level IV data. The valid data are Level IV data and are considered usable for site characterization, human health and environmental risk assessments, evaluation of remedial alternatives,

engineering design or remedial actions, and determination of the potentially responsible party (U.S. EPA 1987).

Data that have not yet undergone the data validation process, or unvalidated data, may not be as usable as the validated Level IV data. According to EPA's *Guidance for Data Useability in Risk Assessment* (U.S. EPA 1990b), unvalidated data may be used in risk assessments only qualitatively to identify analytes during preparation of a sampling and analysis plan. The data used for a baseline risk assessment must also meet criteria for analytical precision, accuracy, representativeness, completeness, and comparability. These data quality parameters were not addressed as part of this study but should be evaluated to establish data usability for risk assessments. The data required to evaluate laboratory precision and accuracy are not currently available to data users from RFEDS. In addition, the detection limits reported by the laboratory should be summarized and compared to health-risk-based detection-limit requirements.

TABLE 2-1 SUMMARY OF FIELD-BLANK RESULTS FOR DISSOLVED AND TOTAL METALS BY YEAR

| Analyte   | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|-----------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|           |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| DISSOLVED |      |               |                 |                   |                 |                     |                |                |                |
| Aluminum  | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 28            | 0               | 24                | 4               | 0.14                | 33.0000        | 83.4000        | 52.1250        |
|           | 1988 | 55            | 0               | 27                | 28              | 0.51                | 29.3000        | 205.4000       | 58.1929        |
|           | 1989 | 95            | 1               | 55                | 39              | 0.41                | 15.4000        | 151.0000       | 45.5359        |
|           | 1990 | 30            | 0               | 18                | 12              | 0.40                | 16.6000        | 231.0000       | 56.2417        |
| Antimony  | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 28            | 0               | 27                | 1               | 0.04                | 20.0000        | 20.0000        | 20.0000        |
|           | 1988 | 55            | 0               | 54                | 1               | 0.02                | 110.2000       | 110.2000       | 110.2000       |
|           | 1989 | 96            | 1               | 93                | 2               | 0.02                | 50.0000        | 141.0000       | 95.5000        |
|           | 1990 | 31            | 0               | 27                | 4               | 0.13                | 16.1000        | 23.9000        | 18.3750        |
| Arsenic   | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1988 | 55            | 0               | 53                | 2               | 0.04                | 6.0000         | 6.0000         | 6.0000         |
|           | 1989 | 87            | 1               | 83                | 3               | 0.03                | 1.6000         | 35.0000        | 12.9333        |
|           | 1990 | 30            | 0               | 29                | 1               | 0.03                | 1.0000         | 1.0000         | 1.0000         |
| Barium    | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1988 | 55            | 0               | 54                | 1               | 0.02                | 17.0000        | 17.0000        | 17.0000        |
|           | 1989 | 95            | 1               | 44                | 50              | 0.53                | 1.0000         | 15.5000        | 2.7340         |
|           | 1990 | 30            | 0               | 15                | 15              | 0.50                | 1.1000         | 12.4000        | 4.4667         |
| Beryllium | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 28            | 0               | 27                | 1               | 0.04                | 0.6000         | 0.6000         | 0.6000         |
|           | 1988 | 55            | 0               | 51                | 4               | 0.07                | 1.0000         | 2.3000         | 1.3250         |
|           | 1989 | 96            | 1               | 93                | 2               | 0.02                | 1.0000         | 2.0000         | 1.5000         |
|           | 1990 | 30            | 0               | 29                | 1               | 0.03                | 4.8000         | 4.8000         | 4.8000         |
| Cadmium   | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 28            | 0               | 26                | 2               | 0.07                | 0.5000         | 0.7000         | 0.6000         |
|           | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1989 | 96            | 1               | 94                | 1               | 0.01                | 20.2000        | 20.2000        | 20.2000        |
|           | 1990 | 30            | 1               | 28                | 1               | 0.03                | 2.4000         | 2.4000         | 2.4000         |
| Calcium   | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 28            | 0               | 25                | 3               | 0.11                | 990.6000       | 3017.300       | 2185.733       |
|           | 1988 | 55            | 0               | 52                | 3               | 0.05                | 750.4000       | 230833.3       | 77613.10       |
|           | 1989 | 96            | 1               | 77                | 18              | 0.19                | 56.1000        | 1865.200       | 609.6500       |
|           | 1990 | 29            | 0               | 10                | 19              | 0.66                | 43.5000        | 223.0000       | 127.9526       |

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TABLE 2-1 (cont.)

| Analyte           | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|-------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                   |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| DISSOLVED (cont.) |      |               |                 |                   |                 |                     |                |                |                |
| Cesium            | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1989 | 87            | 1               | 86                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1990 | 28            | 0               | 24                | 4               | 0.14                | 100.0000       | 200.0000       | 175.0000       |
| Chromium          | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 22                | 6               | 0.21                | 12.8000        | 44.1000        | 20.4500        |
|                   | 1988 | 55            | 0               | 48                | 7               | 0.13                | 13.5000        | 31.5000        | 21.4000        |
|                   | 1989 | 96            | 1               | 93                | 2               | 0.02                | 10.9000        | 12.0000        | 11.4500        |
|                   | 1990 | 31            | 0               | 27                | 4               | 0.13                | 6.7000         | 8.3000         | 7.5000         |
| Cobalt            | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1989 | 96            | 1               | 95                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1990 | 30            | 0               | 29                | 1               | 0.03                | 5.0000         | 5.0000         | 5.0000         |
| Copper            | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 18                | 10              | 0.36                | 6.5000         | 15.9000        | 8.7600         |
|                   | 1988 | 55            | 0               | 37                | 18              | 0.33                | 6.4000         | 50.5000        | 17.3444        |
|                   | 1989 | 96            | 1               | 92                | 3               | 0.03                | 4.0000         | 32.3000        | 15.7000        |
|                   | 1990 | 31            | 0               | 26                | 5               | 0.16                | 5.2000         | 16.5000        | 8.9000         |
| Cyanide           | 1990 | 3             | 0               | 3                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Iron              | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 5                 | 23              | 0.82                | 11.1000        | 197.9000       | 46.9870        |
|                   | 1988 | 55            | 0               | 3                 | 52              | 0.95                | 7.9000         | 396.8000       | 49.8942        |
|                   | 1989 | 95            | 1               | 71                | 23              | 0.24                | 8.9000         | 178.7000       | 55.1478        |
|                   | 1990 | 30            | 0               | 19                | 11              | 0.37                | 8.6000         | 200.0000       | 49.6818        |
| Lead              | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 23                | 5               | 0.18                | 3.0000         | 34.0000        | 16.4000        |
|                   | 1988 | 55            | 0               | 52                | 3               | 0.05                | 3.0000         | 13.0000        | 6.3333         |
|                   | 1989 | 87            | 1               | 65                | 21              | 0.24                | 1.0000         | 88.0000        | 10.3810        |
|                   | 1990 | 31            | 0               | 28                | 3               | 0.10                | 1.3000         | 5.0000         | 3.2333         |
| Lithium           | 1987 | 8             | 0               | 8                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1988 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1989 | 29            | 1               | 27                | 1               | 0.03                | 1800.000       | 1800.000       | 1800.000       |
|                   | 1990 | 29            | 0               | 26                | 3               | 0.10                | 5.7000         | 67.6000        | 26.4667        |
| Magnesium         | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 21                | 7               | 0.25                | 26.4000        | 523.6000       | 194.6286       |
|                   | 1988 | 54            | 0               | 35                | 19              | 0.35                | 20.6000        | 159.7000       | 52.9947        |

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TABLE 2-1 (cont.)

| Analyte           | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|-------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                   |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| DISSOLVED (cont.) |      |               |                 |                   |                 |                     |                |                |                |
| Manganese         | 1989 | 95            | 1               | 86                | 8               | 0.08                | 29.5000        | 113.5000       | 54.1625        |
|                   | 1990 | 30            | 0               | 16                | 14              | 0.47                | 16.4000        | 119.0000       | 53.2786        |
|                   | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1988 | 55            | 0               | 54                | 1               | 0.02                | 113.8000       | 113.8000       | 113.8000       |
| Mercury           | 1989 | 96            | 1               | 94                | 1               | 0.01                | 2.0000         | 2.0000         | 2.0000         |
|                   | 1990 | 29            | 0               | 14                | 15              | 0.52                | 1.3000         | 8.3000         | 3.9800         |
|                   | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 26                | 2               | 0.07                | 0.1000         | 0.2000         | 0.1500         |
|                   | 1988 | 55            | 0               | 54                | 1               | 0.02                | 0.2000         | 0.2000         | 0.2000         |
| Molybdenum        | 1989 | 85            | 1               | 81                | 3               | 0.04                | 0.2000         | 0.2000         | 0.2000         |
|                   | 1990 | 29            | 1               | 27                | 1               | 0.03                | 0.3000         | 0.3000         | 0.3000         |
|                   | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Nickel            | 1989 | 96            | 1               | 94                | 1               | 0.01                | 13.6000        | 13.6000        | 13.6000        |
|                   | 1990 | 29            | 0               | 22                | 7               | 0.24                | 2.9000         | 28.7000        | 9.0571         |
|                   | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 27                | 1               | 0.04                | 49.9000        | 49.9000        | 49.9000        |
|                   | 1988 | 55            | 0               | 54                | 1               | 0.02                | 60.8000        | 60.8000        | 60.8000        |
| Phosphorus        | 1989 | 96            | 1               | 93                | 2               | 0.02                | 28.3000        | 28.4000        | 28.3500        |
|                   | 1990 | 30            | 0               | 26                | 4               | 0.13                | 4.6000         | 9.1000         | 6.6000         |
|                   | 1990 | 5             | 0               | 1                 | 4               | 0.80                | 92.5000        | 154.0000       | 110.7500       |
| Potassium         | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 22                | 6               | 0.21                | 20.0000        | 540.0000       | 125.0000       |
|                   | 1988 | 54            | 0               | 53                | 1               | 0.02                | 400.0000       | 400.0000       | 400.0000       |
|                   | 1989 | 85            | 1               | 78                | 6               | 0.07                | 220.0000       | 445.0000       | 307.3333       |
|                   | 1990 | 30            | 0               | 22                | 8               | 0.27                | 40.5000        | 1950.000       | 877.5625       |
| Selenium          | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1988 | 55            | 0               | 53                | 2               | 0.04                | 3.0000         | 3.0000         | 3.0000         |
|                   | 1989 | 87            | 1               | 83                | 3               | 0.03                | 1.3000         | 10.6000        | 7.2667         |
|                   | 1990 | 30            | 0               | 28                | 2               | 0.07                | 0.8000         | 81.0000        | 40.9000        |
| Silicon           | 1990 | 5             | 0               | 2                 | 3               | 0.60                | 126.0000       | 714.0000       | 350.3333       |
| Silver            | 1986 | 66            | 66              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1988 | 55            | 0               | 54                | 1               | 0.02                | 46.6000        | 46.6000        | 46.6000        |
|                   | 1989 | 96            | 1               | 93                | 2               | 0.02                | 4.0000         | 4.6000         | 4.3000         |

TABLE 2-1 (cont.)

| Analyte           | Year | Total<br>Samples | Number<br>Rejected | Number<br>Undetected | Number<br>Detected | Detection<br>Frequency | Concentration     |                   |                   |
|-------------------|------|------------------|--------------------|----------------------|--------------------|------------------------|-------------------|-------------------|-------------------|
|                   |      |                  |                    |                      |                    |                        | Minimum<br>(µg/L) | Maximum<br>(µg/L) | Average<br>(µg/L) |
| DISSOLVED (cont.) |      |                  |                    |                      |                    |                        |                   |                   |                   |
| Sodium            | 1990 | 29               | 0                  | 18                   | 11                 | 0.38                   | 2.3000            | 9.9000            | 4.6545            |
|                   | 1986 | 66               | 66                 | 0                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                   | 1987 | 28               | 0                  | 25                   | 3                  | 0.11                   | 2229.900          | 2764.200          | 2416.700          |
|                   | 1988 | 55               | 0                  | 41                   | 14                 | 0.25                   | 2134.700          | 280761.9          | 27292.54          |
|                   | 1989 | 96               | 1                  | 76                   | 19                 | 0.20                   | 236.0000          | 50900.00          | 4572.474          |
| Strontium         | 1990 | 30               | 0                  | 14                   | 16                 | 0.53                   | 52.8000           | 276.0000          | 130.7750          |
|                   | 1986 | 66               | 66                 | 0                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                   | 1987 | 28               | 0                  | 28                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                   | 1988 | 55               | 0                  | 54                   | 1                  | 0.02                   | 3497.400          | 3497.400          | 3497.400          |
|                   | 1989 | 96               | 1                  | 94                   | 1                  | 0.01                   | 1950.000          | 1950.000          | 1950.000          |
| Thallium          | 1990 | 27               | 0                  | 14                   | 13                 | 0.48                   | 1.3000            | 2.9000            | 2.0000            |
|                   | 1989 | 87               | 1                  | 86                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                   | 1990 | 30               | 0                  | 30                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Tin               | 1989 | 30               | 1                  | 29                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                   | 1990 | 29               | 0                  | 23                   | 6                  | 0.21                   | 11.3000           | 47.3000           | 21.7833           |
| Vanadium          | 1986 | 66               | 66                 | 0                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                   | 1987 | 28               | 0                  | 26                   | 2                  | 0.07                   | 25.5000           | 33.7000           | 29.6000           |
|                   | 1988 | 55               | 0                  | 54                   | 1                  | 0.02                   | 24.2000           | 24.2000           | 24.2000           |
|                   | 1989 | 96               | 1                  | 87                   | 8                  | 0.08                   | 12.3000           | 42.3000           | 28.9625           |
|                   | 1990 | 30               | 0                  | 21                   | 9                  | 0.30                   | 2.3000            | 19.8000           | 8.1444            |
| Zinc              | 1986 | 66               | 66                 | 0                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                   | 1987 | 28               | 0                  | 24                   | 4                  | 0.14                   | 28.5000           | 50.0000           | 37.1250           |
|                   | 1988 | 55               | 0                  | 26                   | 29                 | 0.53                   | 20.3000           | 294.6000          | 65.1310           |
|                   | 1989 | 95               | 1                  | 73                   | 21                 | 0.22                   | 3.1000            | 76.5000           | 21.6667           |
|                   | 1990 | 30               | 0                  | 16                   | 14                 | 0.47                   | 3.5000            | 34.6000           | 12.7429           |
| TOTAL             |      |                  |                    |                      |                    |                        |                   |                   |                   |
| Aluminum          | 1990 | 6                | 0                  | 3                    | 3                  | 0.50                   | 15.2000           | 109.0000          | 50.0667           |
| Antimony          | 1990 | 7                | 0                  | 6                    | 1                  | 0.14                   | 8.9000            | 8.9000            | 8.9000            |
| Arsenic           | 1990 | 7                | 0                  | 6                    | 1                  | 0.14                   | 1.0000            | 1.0000            | 1.0000            |
| Barium            | 1990 | 7                | 0                  | 2                    | 5                  | 0.71                   | 1.8000            | 14.4000           | 5.6400            |
| Beryllium         | 1990 | 7                | 0                  | 7                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Cadmium           | 1990 | 7                | 0                  | 7                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Calcium           | 1990 | 6                | 0                  | 0                    | 6                  | 1.00                   | 79.8000           | 241.0000          | 165.4667          |
| Cesium            | 1990 | 7                | 0                  | 6                    | 1                  | 0.14                   | 200.0000          | 200.0000          | 200.0000          |
| Chromium          | 1990 | 7                | 0                  | 7                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Cobalt            | 1990 | 7                | 0                  | 7                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |

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TABLE 2-1 (cont.)

| Analyte       | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|---------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|               |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| TOTAL (cont.) |      |               |                 |                   |                 |                     |                |                |                |
| Copper        | 1990 | 7             | 0               | 5                 | 2               | 0.29                | 2.3000         | 13.1000        | 7.7000         |
| Cyanide       | 1990 | 17            | 0               | 15                | 2               | 0.12                | 2.5000         | 3.5000         | 3.0000         |
| Iron          | 1990 | 6             | 0               | 3                 | 3               | 0.50                | 36.4000        | 97.7000        | 64.1667        |
| Lead          | 1990 | 7             | 0               | 6                 | 1               | 0.14                | 1.0000         | 1.0000         | 1.0000         |
| Lithium       | 1990 | 7             | 0               | 6                 | 1               | 0.14                | 5.5000         | 5.5000         | 5.5000         |
| Magnesium     | 1990 | 6             | 0               | 3                 | 3               | 0.50                | 17.1000        | 110.0000       | 52.8000        |
| Manganese     | 1990 | 6             | 0               | 1                 | 5               | 0.83                | 1.3000         | 4.8000         | 3.5600         |
| Mercury       | 1990 | 7             | 1               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Molybdenum    | 1990 | 7             | 0               | 4                 | 3               | 0.43                | 2.2000         | 4.6000         | 3.0000         |
| Nickel        | 1990 | 7             | 0               | 7                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Phosphorus    | 1990 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Potassium     | 1990 | 7             | 0               | 5                 | 2               | 0.29                | 44.3000        | 888.0000       | 466.1500       |
| Selenium      | 1990 | 7             | 0               | 7                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Silicon       | 1990 | 1             | 1               | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Silver        | 1990 | 7             | 0               | 6                 | 1               | 0.14                | 6.3000         | 6.3000         | 6.3000         |
| Sodium        | 1990 | 6             | 0               | 0                 | 6               | 1.00                | 35.0000        | 288.0000       | 131.1167       |
| Strontium     | 1990 | 6             | 0               | 0                 | 6               | 1.00                | 1.3000         | 2.7000         | 1.8167         |
| Thallium      | 1990 | 7             | 0               | 7                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Tin           | 1990 | 7             | 0               | 5                 | 2               | 0.29                | 9.7000         | 12.1000        | 10.9000        |
| Vanadium      | 1990 | 6             | 0               | 4                 | 2               | 0.33                | 3.2000         | 5.9000         | 4.5500         |
| Zinc          | 1990 | 6             | 0               | 0                 | 6               | 1.00                | 3.3000         | 24.3000        | 10.4000        |

TABLE 2-2 SUMMARY OF TRIP-BLANK RESULTS FOR DISSOLVED METALS BY YEAR

| Analyte   | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|-----------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|           |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| Aluminum  | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 40            | 0               | 35                | 5               | 0.13                | 29.0000        | 45.5000        | 35.2600        |
|           | 1988 | 55            | 0               | 38                | 17              | 0.31                | 29.6000        | 95.3000        | 47.2471        |
|           | 1989 | 66            | 0               | 34                | 32              | 0.48                | 15.4000        | 143.5000       | 47.2500        |
| Antimony  | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 42            | 0               | 41                | 1               | 0.02                | 6.0000         | 6.0000         | 6.0000         |
|           | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1989 | 67            | 0               | 67                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Arsenic   | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 42            | 0               | 42                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1988 | 55            | 0               | 52                | 3               | 0.05                | 6.0000         | 29.2000        | 14.0667        |
|           | 1989 | 58            | 0               | 53                | 5               | 0.09                | 1.4000         | 14.6000        | 6.3000         |
| Barium    | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 40            | 0               | 40                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1989 | 65            | 0               | 18                | 47              | 0.72                | 1.1000         | 4.1000         | 2.3851         |
| Beryllium | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 40            | 0               | 37                | 3               | 0.08                | 0.3000         | 4.0000         | 2.1000         |
|           | 1988 | 55            | 0               | 53                | 2               | 0.04                | 1.4000         | 2.0000         | 1.7000         |
|           | 1989 | 67            | 0               | 66                | 1               | 0.01                | 2.7000         | 2.7000         | 2.7000         |
| Cadmium   | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 42            | 0               | 41                | 1               | 0.02                | 0.5000         | 0.5000         | 0.5000         |
|           | 1988 | 55            | 0               | 53                | 2               | 0.04                | 1.0000         | 1.0000         | 1.0000         |
|           | 1989 | 67            | 0               | 67                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Calcium   | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 40            | 0               | 37                | 3               | 0.08                | 1641.700       | 2966.800       | 2338.667       |
|           | 1988 | 55            | 0               | 52                | 3               | 0.05                | 899.2000       | 1589.300       | 1359.267       |
|           | 1989 | 67            | 0               | 60                | 7               | 0.10                | 561.0000       | 901.0000       | 719.0143       |
| Cesium    | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 42            | 0               | 42                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1989 | 58            | 0               | 58                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Chromium  | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 40            | 0               | 35                | 5               | 0.13                | 12.9000        | 22.2000        | 17.5400        |
|           | 1988 | 55            | 0               | 51                | 4               | 0.07                | 11.5000        | 20.4000        | 14.4750        |
|           | 1989 | 67            | 0               | 66                | 1               | 0.01                | 9.9000         | 9.9000         | 9.9000         |
| Cobalt    | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |

TABLE 2-2 (cont.)

| Analyte    | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|            |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| Copper     | 1987 | 40            | 0               | 40                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1989 | 67            | 0               | 67                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1987 | 40            | 0               | 30                | 10              | 0.25                | 7.1000         | 18.7000        | 10.8200        |
| Iron       | 1988 | 55            | 0               | 37                | 18              | 0.33                | 6.8000         | 26.0000        | 13.7222        |
|            | 1989 | 67            | 0               | 65                | 2               | 0.03                | 5.7000         | 26.0000        | 15.8500        |
|            | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1987 | 40            | 0               | 17                | 23              | 0.58                | 7.0000         | 75.8000        | 25.9565        |
|            | 1988 | 55            | 0               | 2                 | 53              | 0.96                | 8.4000         | 179.2000       | 38.4830        |
| Lead       | 1989 | 67            | 0               | 51                | 16              | 0.24                | 8.0000         | 120.2000       | 46.4813        |
|            | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1987 | 42            | 0               | 31                | 11              | 0.26                | 1.0000         | 34.0000        | 11.8182        |
|            | 1988 | 55            | 0               | 49                | 6               | 0.11                | 2.0000         | 28.0000        | 9.8333         |
|            | 1989 | 58            | 0               | 44                | 14              | 0.24                | 1.3000         | 46.0000        | 6.4786         |
| Lithium    | 1987 | 9             | 0               | 9                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1988 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Magnesium  | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1987 | 40            | 0               | 29                | 11              | 0.28                | 20.7000        | 559.5000       | 142.7818       |
|            | 1988 | 55            | 0               | 34                | 21              | 0.38                | 20.0000        | 367.9000       | 74.8000        |
|            | 1989 | 67            | 0               | 64                | 3               | 0.04                | 27.3000        | 60.3000        | 41.6667        |
|            | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Manganese  | 1987 | 40            | 0               | 40                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1988 | 55            | 0               | 53                | 2               | 0.04                | 6.2000         | 6.2000         | 6.2000         |
|            | 1989 | 67            | 0               | 67                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1987 | 42            | 0               | 39                | 3               | 0.07                | 0.2000         | 0.2000         | 0.2000         |
| Mercury    | 1988 | 54            | 0               | 54                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1989 | 56            | 0               | 56                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1987 | 40            | 0               | 40                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Molybdenum | 1989 | 67            | 0               | 67                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1987 | 40            | 0               | 40                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1989 | 67            | 0               | 67                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Nickel     | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1987 | 40            | 0               | 39                | 1               | 0.03                | 39.2000        | 39.2000        | 39.2000        |
|            | 1988 | 55            | 0               | 52                | 3               | 0.05                | 37.8000        | 41.1000        | 39.8000        |

TABLE 2-2 (cont.)

| Analyte   | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|-----------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|           |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| Potassium | 1988 | 55            | 0               | 54                | 1               | 0.02                | 300.0000       | 300.0000       | 300.0000       |
|           | 1989 | 58            | 0               | 54                | 4               | 0.07                | 22.0000        | 240.0000       | 168.0000       |
| Selenium  | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 42            | 0               | 41                | 1               | 0.02                | 4.0000         | 4.0000         | 4.0000         |
|           | 1988 | 55            | 0               | 54                | 1               | 0.02                | 3.0000         | 3.0000         | 3.0000         |
|           | 1989 | 58            | 0               | 56                | 2               | 0.03                | 1.1000         | 1.4000         | 1.2500         |
| Silver    | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 40            | 0               | 39                | 1               | 0.03                | 34.2000        | 34.2000        | 34.2000        |
|           | 1988 | 55            | 0               | 53                | 2               | 0.04                | 8.6000         | 11.0000        | 9.8000         |
|           | 1989 | 67            | 0               | 63                | 4               | 0.06                | 4.2000         | 4.8000         | 4.5500         |
| Sodium    | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 40            | 0               | 40                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1988 | 55            | 0               | 39                | 16              | 0.29                | 2136.100       | 28196.00       | 7476.719       |
|           | 1989 | 67            | 0               | 57                | 10              | 0.15                | 2416.900       | 3516.500       | 2937.870       |
| Strontium | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 40            | 0               | 40                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1989 | 67            | 0               | 67                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Thallium  | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 42            | 0               | 42                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1988 | 55            | 0               | 55                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1989 | 58            | 0               | 58                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Vanadium  | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 40            | 0               | 38                | 2               | 0.05                | 24.6000        | 41.5000        | 33.0500        |
|           | 1988 | 55            | 0               | 53                | 2               | 0.04                | 31.7000        | 31.9000        | 31.8000        |
|           | 1989 | 67            | 0               | 62                | 5               | 0.07                | 15.5000        | 41.5000        | 27.5600        |
| Zinc      | 1986 | 64            | 64              | 0                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|           | 1987 | 42            | 0               | 34                | 8               | 0.19                | 20.0000        | 80.0000        | 40.4375        |
|           | 1988 | 55            | 0               | 27                | 28              | 0.51                | 20.3000        | 105.1000       | 48.9643        |
|           | 1989 | 67            | 0               | 50                | 17              | 0.25                | 5.8000         | 68.7000        | 16.5882        |

**TABLE 2-3 SUMMARY OF EQUIPMENT-RINSATE-BLANK RESULTS FOR  
DISSOLVED AND TOTAL METALS BY YEAR**

| Analyte   | Year | Total<br>Samples | Number<br>Rejected | Number<br>Undetected | Number<br>Detected | Detection<br>Frequency | Concentration     |                   |                   |
|-----------|------|------------------|--------------------|----------------------|--------------------|------------------------|-------------------|-------------------|-------------------|
|           |      |                  |                    |                      |                    |                        | Minimum<br>(µg/L) | Maximum<br>(µg/L) | Average<br>(µg/L) |
| DISSOLVED |      |                  |                    |                      |                    |                        |                   |                   |                   |
| Aluminum  | 1990 | 29               | 0                  | 15                   | 14                 | 0.48                   | 10.6000           | 234.0000          | 63.3357           |
|           | 1991 | 44               | 0                  | 37                   | 7                  | 0.16                   | 9.6000            | 51.2000           | 27.2286           |
|           | 1992 | 66               | 3                  | 48                   | 15                 | 0.23                   | 6.4000            | 40.0000           | 18.7067           |
| Antimony  | 1990 | 30               | 0                  | 26                   | 4                  | 0.13                   | 11.1000           | 14.2000           | 12.8750           |
|           | 1991 | 45               | 2                  | 36                   | 7                  | 0.16                   | 8.1000            | 42.7000           | 21.8000           |
|           | 1992 | 66               | 1                  | 61                   | 4                  | 0.06                   | 11.5000           | 19.4000           | 15.3250           |
| Arsenic   | 1990 | 29               | 0                  | 29                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|           | 1991 | 45               | 0                  | 45                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|           | 1992 | 66               | 1                  | 65                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Barium    | 1990 | 30               | 0                  | 12                   | 18                 | 0.60                   | 1.2000            | 258.0000          | 21.0500           |
|           | 1991 | 45               | 0                  | 29                   | 16                 | 0.36                   | 1.1000            | 8.2000            | 3.2313            |
|           | 1992 | 66               | 0                  | 63                   | 3                  | 0.05                   | 1.0000            | 3.0000            | 2.2000            |
| Beryllium | 1990 | 29               | 0                  | 29                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|           | 1991 | 45               | 0                  | 45                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|           | 1992 | 66               | 0                  | 66                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Cadmium   | 1990 | 30               | 1                  | 27                   | 2                  | 0.07                   | 3.8000            | 7.0000            | 5.4000            |
|           | 1991 | 45               | 0                  | 42                   | 3                  | 0.07                   | 1.0000            | 2.6000            | 2.0667            |
|           | 1992 | 66               | 0                  | 65                   | 1                  | 0.02                   | 2.3000            | 2.3000            | 2.3000            |
| Calcium   | 1990 | 28               | 0                  | 4                    | 24                 | 0.86                   | 41.0000           | 174000.0          | 8119.288          |
|           | 1991 | 44               | 0                  | 11                   | 33                 | 0.75                   | 55.4000           | 1880.000          | 246.7455          |
|           | 1992 | 66               | 0                  | 33                   | 33                 | 0.50                   | 29.6000           | 798.0000          | 180.0273          |
| Cesium    | 1990 | 29               | 0                  | 23                   | 6                  | 0.21                   | 100.0000          | 300.0000          | 183.3333          |
|           | 1991 | 45               | 0                  | 44                   | 1                  | 0.02                   | 120.0000          | 120.0000          | 120.0000          |
|           | 1992 | 66               | 8                  | 58                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Chromium  | 1990 | 30               | 0                  | 29                   | 1                  | 0.03                   | 10.3000           | 10.3000           | 10.3000           |
|           | 1991 | 45               | 0                  | 42                   | 3                  | 0.07                   | 5.1000            | 12.0000           | 9.2667            |
|           | 1992 | 66               | 0                  | 65                   | 1                  | 0.02                   | 2.6000            | 2.6000            | 2.6000            |
| Cobalt    | 1990 | 29               | 0                  | 29                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|           | 1991 | 45               | 0                  | 42                   | 3                  | 0.07                   | 3.0000            | 5.2000            | 4.0000            |
|           | 1992 | 66               | 1                  | 64                   | 1                  | 0.02                   | 3.0000            | 3.0000            | 3.0000            |
| Copper    | 1990 | 30               | 0                  | 21                   | 9                  | 0.30                   | 2.0000            | 15.6000           | 4.2333            |
|           | 1991 | 45               | 0                  | 39                   | 6                  | 0.13                   | 2.1000            | 7.1000            | 4.4833            |
|           | 1992 | 66               | 0                  | 58                   | 8                  | 0.12                   | 2.0000            | 12.8000           | 4.3625            |

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TABLE 2-3 (cont.)

| Analyte           | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|-------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                   |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| DISSOLVED (cont.) |      |               |                 |                   |                 |                     |                |                |                |
| Cyanide           | 1991 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Iron              | 1990 | 29            | 0               | 14                | 15              | 0.52                | 3.2000         | 282.0000       | 54.7733        |
|                   | 1991 | 45            | 0               | 30                | 15              | 0.33                | 2.8000         | 184.0000       | 51.1800        |
|                   | 1992 | 66            | 1               | 46                | 19              | 0.29                | 4.6000         | 100.0000       | 28.4211        |
| Lead              | 1990 | 29            | 0               | 23                | 6               | 0.21                | 0.7000         | 45.3000        | 10.8167        |
|                   | 1991 | 45            | 0               | 44                | 1               | 0.02                | 1.2000         | 1.2000         | 1.2000         |
|                   | 1992 | 66            | 0               | 62                | 4               | 0.06                | 1.4000         | 2.3000         | 1.9750         |
| Lithium           | 1990 | 30            | 0               | 26                | 4               | 0.13                | 6.1000         | 41.3000        | 15.3500        |
|                   | 1991 | 45            | 1               | 39                | 5               | 0.11                | 1.0000         | 3.9000         | 2.5000         |
|                   | 1992 | 66            | 0               | 56                | 10              | 0.15                | 1.0000         | 13.2000        | 3.0000         |
| Magnesium         | 1990 | 29            | 0               | 17                | 12              | 0.41                | 15.6000        | 3850.000       | 389.0833       |
|                   | 1991 | 45            | 2               | 26                | 17              | 0.38                | 12.6000        | 67.6000        | 26.8647        |
|                   | 1992 | 66            | 2               | 47                | 17              | 0.26                | 9.3000         | 43.2000        | 23.1824        |
| Manganese         | 1990 | 26            | 0               | 3                 | 23              | 0.88                | 1.6000         | 34.6000        | 5.1304         |
|                   | 1991 | 43            | 0               | 2                 | 41              | 0.95                | 1.2000         | 18.9000        | 3.9317         |
|                   | 1992 | 66            | 0               | 39                | 27              | 0.41                | 1.3000         | 13.5000        | 3.6444         |
| Mercury           | 1990 | 29            | 2               | 27                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                   | 1991 | 45            | 0               | 41                | 4               | 0.09                | 0.2100         | 0.2800         | 0.2475         |
|                   | 1992 | 66            | 0               | 62                | 4               | 0.06                | 0.2100         | 0.6400         | 0.3375         |
| Molybdenum        | 1990 | 30            | 0               | 24                | 6               | 0.20                | 2.2000         | 9.7000         | 5.3000         |
|                   | 1991 | 45            | 0               | 36                | 9               | 0.20                | 3.1000         | 10.0000        | 6.7889         |
|                   | 1992 | 66            | 0               | 65                | 1               | 0.02                | 8.0000         | 8.0000         | 8.0000         |
| Nickel            | 1990 | 30            | 0               | 27                | 3               | 0.10                | 4.3000         | 17.3000        | 9.0000         |
|                   | 1991 | 45            | 0               | 41                | 4               | 0.09                | 5.0000         | 18.9000        | 9.2250         |
|                   | 1992 | 66            | 1               | 62                | 3               | 0.05                | 2.1000         | 13.4000        | 6.1000         |
| Phosphorus        | 1990 | 6             | 0               | 4                 | 2               | 0.33                | 134.0000       | 158.0000       | 146.0000       |
| Potassium         | 1990 | 29            | 0               | 18                | 11              | 0.38                | 36.2000        | 2890.000       | 1059.545       |
|                   | 1991 | 45            | 0               | 36                | 9               | 0.20                | 74.5000        | 307.0000       | 128.3222       |
|                   | 1992 | 66            | 0               | 56                | 10              | 0.15                | 38.1000        | 290.0000       | 119.0400       |
| Selenium          | 1990 | 29            | 0               | 27                | 2               | 0.07                | 2.0000         | 20.0000        | 11.0000        |
|                   | 1991 | 45            | 0               | 44                | 1               | 0.02                | 1.0000         | 1.0000         | 1.0000         |
|                   | 1992 | 66            | 0               | 65                | 1               | 0.02                | 1.6000         | 1.6000         | 1.6000         |
| Silica            | 1991 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Silicon           | 1990 | 7             | 0               | 3                 | 4               | 0.57                | 127.0000       | 344.0000       | 235.0000       |
|                   | 1991 | 4             | 0               | 3                 | 1               | 0.25                | 86.7000        | 86.7000        | 86.7000        |
|                   | 1992 | 47            | 0               | 29                | 18              | 0.38                | 44.6000        | 190.0000       | 97.9389        |

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**TABLE 2-3 (cont.)**

| Analyte           | Year | Total<br>Samples | Number<br>Rejected | Number<br>Undetected | Number<br>Detected | Detection<br>Frequency | Concentration     |                   |                   |
|-------------------|------|------------------|--------------------|----------------------|--------------------|------------------------|-------------------|-------------------|-------------------|
|                   |      |                  |                    |                      |                    |                        | Minimum<br>(µg/L) | Maximum<br>(µg/L) | Average<br>(µg/L) |
| DISSOLVED (cont.) |      |                  |                    |                      |                    |                        |                   |                   |                   |
| Silver            | 1990 | 28               | 0                  | 18                   | 10                 | 0.36                   | 2.3000            | 8.5000            | 4.4500            |
|                   | 1991 | 45               | 1                  | 37                   | 7                  | 0.16                   | 2.3000            | 4.5000            | 3.2571            |
|                   | 1992 | 66               | 1                  | 65                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Sodium            | 1990 | 28               | 0                  | 5                    | 23                 | 0.82                   | 51.4000           | 12300.00          | 742.0391          |
|                   | 1991 | 45               | 0                  | 22                   | 23                 | 0.51                   | 33.7000           | 1750.000          | 298.9435          |
|                   | 1992 | 66               | 0                  | 31                   | 35                 | 0.53                   | 67.6000           | 6990.000          | 527.3000          |
| Strontium         | 1990 | 28               | 0                  | 8                    | 20                 | 0.71                   | 1.1000            | 1340.000          | 73.2050           |
|                   | 1991 | 45               | 0                  | 11                   | 34                 | 0.76                   | 1.4000            | 7.3000            | 2.7882            |
|                   | 1992 | 66               | 0                  | 53                   | 13                 | 0.20                   | 1.0000            | 6.6000            | 2.3077            |
| Thallium          | 1990 | 29               | 0                  | 28                   | 1                  | 0.03                   | 3.0000            | 3.0000            | 3.0000            |
|                   | 1991 | 45               | 0                  | 43                   | 2                  | 0.04                   | 1.0000            | 1.0000            | 1.0000            |
|                   | 1992 | 66               | 0                  | 65                   | 1                  | 0.02                   | 1.1000            | 1.1000            | 1.1000            |
| Tin               | 1990 | 30               | 0                  | 23                   | 7                  | 0.23                   | 12.4000           | 53.7000           | 28.1000           |
|                   | 1991 | 45               | 0                  | 42                   | 3                  | 0.07                   | 11.2000           | 21.3000           | 15.8667           |
|                   | 1992 | 66               | 1                  | 63                   | 2                  | 0.03                   | 23.7000           | 28.9000           | 26.3000           |
| Vanadium          | 1990 | 29               | 0                  | 21                   | 8                  | 0.28                   | 2.1000            | 30.2000           | 8.9875            |
|                   | 1991 | 45               | 0                  | 40                   | 5                  | 0.11                   | 2.0000            | 4.1000            | 3.1800            |
|                   | 1992 | 66               | 2                  | 56                   | 8                  | 0.12                   | 1.3000            | 4.0000            | 2.3000            |
| Zinc              | 1990 | 28               | 0                  | 9                    | 19                 | 0.68                   | 3.5000            | 17.9000           | 8.9421            |
|                   | 1991 | 45               | 0                  | 22                   | 23                 | 0.51                   | 5.4000            | 58.2000           | 12.0435           |
|                   | 1992 | 66               | 0                  | 45                   | 21                 | 0.32                   | 4.2000            | 28.9000           | 10.7000           |
| TOTAL             |      |                  |                    |                      |                    |                        |                   |                   |                   |
| Aluminum          | 1991 | 28               | 0                  | 23                   | 5                  | 0.18                   | 9.1000            | 31.9000           | 17.7400           |
|                   | 1992 | 66               | 3                  | 43                   | 20                 | 0.30                   | 6.8000            | 8510.000          | 442.0850          |
| Antimony          | 1991 | 28               | 0                  | 25                   | 3                  | 0.11                   | 9.3000            | 15.7000           | 13.3000           |
|                   | 1992 | 66               | 4                  | 59                   | 3                  | 0.05                   | 8.7000            | 12.6000           | 10.0000           |
| Arsenic           | 1991 | 28               | 0                  | 28                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                   | 1992 | 66               | 2                  | 63                   | 1                  | 0.02                   | 1.0000            | 1.0000            | 1.0000            |
| Barium            | 1991 | 26               | 0                  | 16                   | 10                 | 0.38                   | 2.3000            | 9.1000            | 4.2800            |
|                   | 1992 | 66               | 0                  | 49                   | 17                 | 0.26                   | 1.1000            | 63.9000           | 6.2647            |
| Beryllium         | 1991 | 28               | 0                  | 28                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                   | 1992 | 66               | 2                  | 64                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Cadmium           | 1991 | 28               | 0                  | 22                   | 6                  | 0.21                   | 1.2000            | 2.1000            | 1.5333            |
|                   | 1992 | 66               | 1                  | 64                   | 1                  | 0.02                   | 1.5000            | 1.5000            | 1.5000            |
| Calcium           | 1991 | 26               | 0                  | 4                    | 22                 | 0.85                   | 96.5000           | 425.0000          | 214.7955          |
| TOTAL (cont.)     |      |                  |                    |                      |                    |                        |                   |                   |                   |

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**TABLE 2-3 (cont.)**

| Analyte    | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|            |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| Cesium     | 1992 | 66            | 0               | 30                | 36              | 0.55                | 20.6000        | 11900.00       | 511.3000       |
|            | 1991 | 27            | 0               | 24                | 3               | 0.11                | 60.0000        | 80.0000        | 66.6667        |
| Chromium   | 1992 | 66            | 7               | 59                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1991 | 28            | 1               | 22                | 5               | 0.18                | 6.1000         | 6.4000         | 6.2400         |
| Cobalt     | 1992 | 66            | 1               | 63                | 2               | 0.03                | 2.3000         | 20.4000        | 11.3500        |
|            | 1991 | 27            | 0               | 23                | 4               | 0.15                | 2.0000         | 3.5000         | 3.0000         |
| Copper     | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1991 | 28            | 0               | 25                | 3               | 0.11                | 3.3000         | 4.6000         | 3.8667         |
| Cyanide    | 1992 | 66            | 0               | 55                | 11              | 0.17                | 1.0000         | 8.0000         | 3.4364         |
|            | 1990 | 17            | 0               | 15                | 2               | 0.12                | 2.5000         | 2.5000         | 2.5000         |
| Iron       | 1991 | 41            | 0               | 41                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1992 | 45            | 3               | 39                | 3               | 0.07                | 2.7000         | 4.0000         | 3.2000         |
| Lead       | 1991 | 27            | 1               | 15                | 11              | 0.41                | 4.9000         | 117.0000       | 50.4182        |
|            | 1992 | 66            | 0               | 44                | 22              | 0.33                | 4.8000         | 8590.000       | 440.8227       |
| Lithium    | 1991 | 28            | 1               | 27                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1992 | 66            | 0               | 61                | 5               | 0.08                | 0.8000         | 2.9000         | 1.9200         |
| Magnesium  | 1991 | 27            | 1               | 25                | 1               | 0.04                | 1.5000         | 1.5000         | 1.5000         |
|            | 1992 | 66            | 0               | 54                | 12              | 0.18                | 1.0000         | 10.7000        | 2.5333         |
| Manganese  | 1991 | 28            | 1               | 20                | 7               | 0.25                | 15.0000        | 22.3000        | 17.4714        |
|            | 1992 | 66            | 1               | 46                | 19              | 0.29                | 9.1000         | 4190.000       | 240.0684       |
| Mercury    | 1991 | 26            | 0               | 5                 | 21              | 0.81                | 1.1000         | 7.7000         | 3.3381         |
|            | 1992 | 66            | 0               | 39                | 27              | 0.41                | 2.3000         | 78.0000        | 6.7630         |
| Molybdenum | 1991 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1992 | 66            | 0               | 64                | 2               | 0.03                | 0.2100         | 0.2200         | 0.2150         |
| Nickel     | 1991 | 27            | 0               | 26                | 1               | 0.04                | 4.0000         | 4.0000         | 4.0000         |
|            | 1992 | 66            | 0               | 65                | 1               | 0.02                | 2.6000         | 2.6000         | 2.6000         |
| Potassium  | 1991 | 28            | 0               | 26                | 2               | 0.07                | 4.2000         | 4.8000         | 4.5000         |
|            | 1992 | 66            | 2               | 63                | 1               | 0.02                | 14.0000        | 14.0000        | 14.0000        |
| Selenium   | 1991 | 28            | 0               | 25                | 3               | 0.11                | 68.4000        | 83.6000        | 77.2000        |
|            | 1992 | 65            | 0               | 56                | 9               | 0.14                | 61.8000        | 226.0000       | 111.4444       |
| Silicon    | 1991 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|            | 1992 | 66            | 1               | 65                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Silver     | 1991 | 2             | 0               | 1                 | 1               | 0.50                | 170.0000       | 170.0000       | 170.0000       |
|            | 1992 | 48            | 0               | 25                | 23              | 0.48                | 27.9000        | 288.0000       | 116.0913       |
|            | 1991 | 28            | 1               | 25                | 2               | 0.07                | 2.3000         | 2.9000         | 2.6000         |
|            | 1992 | 66            | 0               | 65                | 1               | 0.02                | 12.3000        | 12.3000        | 12.3000        |

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TABLE 2-3 (cont.)

| Analyte       | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|---------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|               |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| TOTAL (cont.) |      |               |                 |                   |                 |                     |                |                |                |
| Sodium        | 1991 | 27            | 0               | 12                | 15              | 0.56                | 55.7000        | 450.0000       | 177.7600       |
|               | 1992 | 66            | 0               | 31                | 35              | 0.53                | 70.3000        | 13700.00       | 1147.171       |
| Strontium     | 1991 | 26            | 0               | 5                 | 21              | 0.81                | 1.8000         | 4.5000         | 2.6905         |
|               | 1992 | 65            | 0               | 51                | 14              | 0.22                | 1.0000         | 75.9000        | 7.3857         |
| Thallium      | 1991 | 28            | 0               | 27                | 1               | 0.04                | 1.0000         | 1.0000         | 1.0000         |
|               | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Tin           | 1991 | 27            | 0               | 26                | 1               | 0.04                | 11.6000        | 11.6000        | 11.6000        |
|               | 1992 | 66            | 0               | 65                | 1               | 0.02                | 11.1000        | 11.1000        | 11.1000        |
| Vanadium      | 1991 | 27            | 0               | 24                | 3               | 0.11                | 2.4000         | 2.8000         | 2.5667         |
|               | 1992 | 65            | 1               | 56                | 8               | 0.12                | 1.5000         | 2.9000         | 1.8500         |
| Zinc          | 1991 | 27            | 0               | 17                | 10              | 0.37                | 2.5000         | 17.2000        | 9.1300         |
|               | 1992 | 66            | 0               | 46                | 20              | 0.30                | 4.8000         | 60.2000        | 16.3450        |

**TABLE 2-4 RELATIVE PERCENT DIFFERENCE FOR  
DISSOLVED AND TOTAL METALS IN FIELD DUPLICATES**

| Analyte    | Number of Duplicate Samples | Relative Percent Difference |         |         | Number Exceeding 20 Percent RPD |
|------------|-----------------------------|-----------------------------|---------|---------|---------------------------------|
|            |                             | Minimum                     | Maximum | Average |                                 |
| DISSOLVED  |                             |                             |         |         |                                 |
| Aluminum   | 89                          | 0                           | 196     | 37      | 54                              |
| Antimony   | 27                          | 1                           | 65      | 21      | 10                              |
| Arsenic    | 19                          | 0                           | 94      | 21      | 5                               |
| Barium     | 168                         | 0                           | 87      | 5       | 5                               |
| Beryllium  | 3                           | 7                           | 48      | 23      | 1                               |
| Cadmium    | 4                           | 3                           | 135     | 53      | 2                               |
| Calcium    | 203                         | 0                           | 164     | 5       | 5                               |
| Cesium     | 4                           | 0                           | 67      | 32      | 2                               |
| Chromium   | 22                          | 1                           | 103     | 26      | 9                               |
| Cobalt     | 14                          | 1                           | 45      | 15      | 4                               |
| Copper     | 27                          | 8                           | 190     | 54      | 19                              |
| Iron       | 79                          | 1                           | 183     | 56      | 51                              |
| Lead       | 24                          | 0                           | 199     | 66      | 17                              |
| Lithium    | 94                          | 0                           | 129     | 9       | 7                               |
| Magnesium  | 195                         | 0                           | 163     | 4       | 3                               |
| Manganese  | 139                         | 0                           | 169     | 28      | 50                              |
| Mercury    | 6                           | 0                           | 116     | 28      | 2                               |
| Molybdenum | 21                          | 0                           | 108     | 28      | 12                              |
| Nickel     | 25                          | 1                           | 164     | 40      | 13                              |
| Phosphorus | 3                           | 1                           | 18      | 7       | 0                               |
| Potassium  | 126                         | 0                           | 109     | 9       | 14                              |
| Selenium   | 25                          | 0                           | 67      | 13      | 4                               |
| Silica     | 1                           | 68                          | 68      | 68      | 1                               |
| Silicon    | 66                          | 0                           | 14      | 3       | 0                               |
| Silver     | 13                          | 0                           | 53      | 22      | 6                               |
| Sodium     | 201                         | 0                           | 199     | 6       | 7                               |
| Strontium  | 176                         | 0                           | 40      | 3       | 1                               |
| Thallium   | 1                           | 0                           | 0       | 0       | 0                               |
| Tin        | 27                          | 0                           | 192     | 25      | 14                              |
| Vanadium   | 53                          | 0                           | 99      | 23      | 21                              |
| Zinc       | 80                          | 1                           | 158     | 34      | 43                              |

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TABLE 2-4 (cont.)

| Analyte    | Number of Duplicate Samples | Relative Percent Difference |         |         | Number Exceeding 20 Percent RPD |
|------------|-----------------------------|-----------------------------|---------|---------|---------------------------------|
|            |                             | Minimum                     | Maximum | Average |                                 |
| TOTAL      |                             |                             |         |         |                                 |
| Aluminum   | 89                          | 0                           | 198     | 50      | 63                              |
| Antimony   | 8                           | 4                           | 72      | 33      | 5                               |
| Arsenic    | 32                          | 0                           | 86      | 22      | 16                              |
| Barium     | 85                          | 0                           | 186     | 23      | 25                              |
| Beryllium  | 12                          | 0                           | 109     | 44      | 6                               |
| Cadmium    | 11                          | 0                           | 132     | 40      | 5                               |
| Calcium    | 94                          | 0                           | 198     | 8       | 8                               |
| Cesium     | 2                           | 13                          | 40      | 27      | 1                               |
| Chromium   | 50                          | 1                           | 150     | 42      | 32                              |
| Cobalt     | 31                          | 2                           | 155     | 45      | 21                              |
| Copper     | 42                          | 2                           | 151     | 40      | 25                              |
| Cyanide    | 7                           | 0                           | 72      | 35      | 5                               |
| Iron       | 89                          | 0                           | 184     | 46      | 60                              |
| Lead       | 71                          | 0                           | 154     | 42      | 46                              |
| Lithium    | 64                          | 0                           | 131     | 23      | 21                              |
| Magnesium  | 93                          | 0                           | 92      | 13      | 16                              |
| Manganese  | 89                          | 0                           | 167     | 42      | 51                              |
| Mercury    | 3                           | 0                           | 14      | 5       | 0                               |
| Molybdenum | 11                          | 0                           | 113     | 30      | 6                               |
| Nickel     | 43                          | 1                           | 156     | 44      | 27                              |
| Potassium  | 75                          | 0                           | 140     | 27      | 31                              |
| Selenium   | 8                           | 0                           | 63      | 18      | 2                               |
| Silicon    | 47                          | 1                           | 123     | 25      | 21                              |
| Silver     | 3                           | 19                          | 37      | 31      | 2                               |
| Sodium     | 93                          | 0                           | 199     | 7       | 5                               |
| Strontium  | 82                          | 0                           | 196     | 11      | 10                              |
| Thallium   | 2                           | 0                           | 6       | 3       | 0                               |
| Tin        | 7                           | 19                          | 96      | 49      | 6                               |
| Vanadium   | 72                          | 2                           | 174     | 42      | 39                              |
| Zinc       | 66                          | 0                           | 163     | 43      | 44                              |

TABLE 2-5 SUMMARY OF FIELD-BLANK RESULTS FOR DISSOLVED AND TOTAL RADIONUCLIDES BY YEAR

| Analyte                            | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration   |                 |                 |
|------------------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|-----------------|-----------------|-----------------|
|                                    |      |               |                 |                   |                 |                     | Minimum (pCi/L) | Maximum (pCi/L) | Average (pCi/L) |
| DISSOLVED                          |      |               |                 |                   |                 |                     |                 |                 |                 |
| Americium-241                      | 1987 | 19            | 19              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 38            | 20              | 0                 | 18              | 0.47                | -0.0100         | 0.1600          | 0.0189          |
|                                    | 1989 | 36            | 1               | 0                 | 35              | 0.97                | -0.0400         | 0.1140          | 0.0130          |
| Cesium-137                         | 1989 | 23            | 1               | 0                 | 22              | 0.96                | -0.2900         | 0.5000          | 0.0036          |
| Gross alpha-dissolved              | 1990 | 23            | 1               | 0                 | 22              | 0.96                | -0.1530         | 86.4000         | 7.8732          |
| Gross alpha-suspended              | 1990 | 3             | 3               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
| Gross alpha particle radioactivity | 1987 | 20            | 20              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 42            | 24              | 0                 | 18              | 0.43                | -1.0000         | 240.0000        | 13.4444         |
|                                    | 1989 | 75            | 1               | 0                 | 74              | 0.99                | -1.0000         | 51.4000         | 1.4446          |
|                                    | 1990 | 1             | 0               | 0                 | 1               | 1.00                | 0.2390          | 0.2390          | 0.2390          |
|                                    | 1990 | 23            | 0               | 0                 | 23              | 1.00                | -0.1680         | 61.7300         | 5.8301          |
| Gross beta-dissolved               | 1990 | 23            | 0               | 0                 | 23              | 1.00                | -0.1680         | 61.7300         | 5.8301          |
| Gross beta-suspended               | 1990 | 3             | 3               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
| Gross beta particle radioactivity  | 1987 | 20            | 20              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 42            | 24              | 0                 | 18              | 0.43                | -4.0000         | 3.0000          | -0.0556         |
|                                    | 1989 | 74            | 1               | 0                 | 73              | 0.99                | -2.6000         | 34.1000         | 2.0849          |
|                                    | 1990 | 1             | 1               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1989 | 5             | 0               | 0                 | 5               | 1.00                | 0.0000          | 0.0000          | 0.0000          |
| Plutonium-239/240                  | 1987 | 19            | 19              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 41            | 23              | 0                 | 18              | 0.44                | -0.0600         | 0.0300          | 0.0017          |
|                                    | 1989 | 45            | 1               | 0                 | 44              | 0.98                | -0.0300         | 0.0230          | 0.0050          |
| Radium-226                         | 1990 | 1             | 0               | 0                 | 1               | 1.00                | 1.7760          | 1.7760          | 1.7760          |
| Strontium-89                       | 1990 | 2             | 2               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
| Strontium-89,90                    | 1987 | 19            | 19              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 2             | 2               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1989 | 18            | 1               | 0                 | 17              | 0.94                | -0.2000         | 0.5000          | 0.1371          |
|                                    | 1990 | 24            | 2               | 0                 | 22              | 0.92                | 0.0855          | 0.5490          | 0.3285          |
|                                    | 1989 | 5             | 0               | 0                 | 5               | 1.00                | -0.2000         | 0.5000          | 0.1600          |
| Strontium-90                       | 1990 | 2             | 2               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1990 | 1             | 1               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
| Total Radiocesium                  | 1990 | 1             | 1               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
| Tritium                            | 1987 | 20            | 20              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 42            | 24              | 0                 | 18              | 0.43                | 190.0000        | 240.0000        | 216.1111        |
|                                    | 1989 | 52            | 3               | 0                 | 49              | 0.94                | -260.000        | 290.0000        | 146.1224        |

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TABLE 2-5 (cont.)

| Analyte                            | Year                              | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration   |                 |                 |        |
|------------------------------------|-----------------------------------|---------------|-----------------|-------------------|-----------------|---------------------|-----------------|-----------------|-----------------|--------|
|                                    |                                   |               |                 |                   |                 |                     | Minimum (pCi/L) | Maximum (pCi/L) | Average (pCi/L) |        |
| DISSOLVED (cont.)                  |                                   |               |                 |                   |                 |                     |                 |                 |                 |        |
| Uranium-233,-234                   | 1990                              | 20            | 0               | 0                 | 20              | 1.00                | -129.000        | 4759.000        | 541.6355        |        |
|                                    | 1987                              | 18            | 18              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |        |
|                                    | 1988                              | 41            | 23              | 0                 | 18              | 0.44                | 0.0000          | 0.2000          | 0.0444          |        |
|                                    | 1989                              | 51            | 1               | 0                 | 50              | 0.98                | 0.0000          | 29.7000         | 1.1932          |        |
| Uranium-235                        | 1990                              | 27            | 1               | 0                 | 26              | 0.96                | -0.0405         | 92.5200         | 8.1310          |        |
|                                    | 1987                              | 18            | 18              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |        |
|                                    | 1988                              | 41            | 23              | 0                 | 18              | 0.44                | 0.0000          | 0.1000          | 0.0056          |        |
|                                    | 1989                              | 51            | 1               | 0                 | 50              | 0.98                | -0.1600         | 0.8500          | 0.0904          |        |
| Uranium-235/236                    | 1990                              | 24            | 0               | 0                 | 24              | 1.00                | -0.0115         | 3.3980          | 0.3475          |        |
|                                    | 1990                              | 3             | 1               | 0                 | 2               | 0.67                | 0.0000          | 0.0000          | 0.0000          |        |
|                                    | Uranium-238                       | 1987          | 18              | 18                | 0               | 0                   | 0.00            | 0.0000          | 0.0000          | 0.0000 |
|                                    |                                   | 1988          | 41              | 23                | 0               | 18                  | 0.44            | -0.1000         | 0.1000          | 0.0183 |
| 1989                               |                                   | 51            | 1               | 0                 | 50              | 0.98                | -0.1600         | 19.0000         | 0.4504          |        |
| 1990                               |                                   | 27            | 1               | 0                 | 26              | 0.96                | -0.0188         | 59.9400         | 5.4984          |        |
| TOTAL                              |                                   |               |                 |                   |                 |                     |                 |                 |                 |        |
| Americium-241                      | 1986                              | 33            | 33              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |        |
|                                    | 1987                              | 9             | 9               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |        |
|                                    | 1989                              | 21            | 5               | 0                 | 16              | 0.76                | -0.0030         | 0.0340          | 0.0116          |        |
|                                    | 1990                              | 56            | 3               | 0                 | 53              | 0.95                | -0.0002         | 0.0112          | 0.0050          |        |
| Cesium                             | 1990                              | 2             | 0               | 0                 | 2               | 1.00                | 0.0000          | 0.1000          | 0.0500          |        |
| Cesium-137                         | 1989                              | 9             | 0               | 0                 | 9               | 1.00                | -0.2900         | 0.4500          | 0.1111          |        |
|                                    | 1990                              | 49            | 3               | 0                 | 46              | 0.94                | -0.4500         | 0.5600          | 0.1524          |        |
| Gross alpha-dissolved              | 1990                              | 9             | 0               | 0                 | 9               | 1.00                | -0.4000         | 0.3000          | 0.1333          |        |
| Gross alpha-suspended              | 1989                              | 3             | 0               | 0                 | 3               | 1.00                | -0.2000         | 0.2000          | 0.0333          |        |
|                                    | 1990                              | 12            | 5               | 0                 | 7               | 0.58                | -0.2495         | 0.4000          | -0.1160         |        |
|                                    | 1986                              | 33            | 33              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |        |
| Gross alpha particle radioactivity | 1987                              | 9             | 9               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |        |
|                                    | 1989                              | 10            | 0               | 0                 | 10              | 1.00                | -0.2000         | 0.4000          | 0.1100          |        |
|                                    | 1990                              | 9             | 0               | 0                 | 9               | 1.00                | -0.1000         | 1.2000          | 0.2898          |        |
|                                    | 1990                              | 9             | 0               | 0                 | 9               | 1.00                | -0.6000         | 0.8000          | 0.2000          |        |
| Gross beta-dissolved               | 1989                              | 3             | 3               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |        |
| Gross beta-suspended               | 1990                              | 12            | 5               | 0                 | 7               | 0.58                | -0.0547         | 1.2000          | 0.3011          |        |
|                                    | 1986                              | 33            | 33              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |        |
|                                    | Gross beta particle radioactivity |               |                 |                   |                 |                     |                 |                 |                 |        |

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TABLE 2-5 (cont.)

| Analyte           | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration   |                 |                 |
|-------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|-----------------|-----------------|-----------------|
|                   |      |               |                 |                   |                 |                     | Minimum (pCi/L) | Maximum (pCi/L) | Average (pCi/L) |
| TOTAL (cont.)     | 1987 | 9             | 9               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                   | 1989 | 10            | 0               | 0                 | 10              | 1.00                | -0.9000         | 1.5000          | 0.1300          |
|                   | 1990 | 9             | 0               | 0                 | 9               | 1.00                | -0.7000         | 1.9000          | 0.4160          |
| Plutonium-238     | 1990 | 14            | 0               | 0                 | 14              | 1.00                | -0.0005         | 0.0079          | 0.0028          |
| Plutonium-239     | 1989 | 22            | 0               | 0                 | 22              | 1.00                | -0.0040         | 0.0240          | 0.0078          |
|                   | 1990 | 7             | 0               | 0                 | 7               | 1.00                | 0.0030          | 0.0100          | 0.0071          |
| Plutonium-239/240 | 1986 | 32            | 0               | 0                 | 32              | 1.00                | -0.1400         | 0.0800          | -0.0119         |
|                   | 1987 | 9             | 0               | 0                 | 9               | 1.00                | 0.0000          | 0.6000          | 0.1244          |
|                   | 1989 | 9             | 3               | 0                 | 6               | 0.67                | 0.0010          | 0.0240          | 0.0088          |
|                   | 1990 | 50            | 6               | 0                 | 44              | 0.88                | -0.0040         | 0.0296          | 0.0037          |
| Strontium-89      | 1990 | 2             | 2               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
| Strontium-89,90   | 1987 | 8             | 0               | 0                 | 8               | 1.00                | 0.6000          | 1.0000          | 0.8250          |
|                   | 1989 | 5             | 2               | 0                 | 3               | 0.60                | -0.0100         | 0.1500          | 0.0800          |
|                   | 1990 | 14            | 2               | 0                 | 12              | 0.86                | 0.0400          | 1.9400          | 0.4433          |
| Strontium-90      | 1989 | 9             | 0               | 0                 | 9               | 1.00                | 0.2900          | 0.7900          | 0.4544          |
|                   | 1990 | 18            | 2               | 0                 | 16              | 0.89                | -0.1200         | 0.6800          | 0.1119          |
| Total Radiocesium | 1989 | 5             | 2               | 0                 | 3               | 0.60                | -0.0600         | 0.0000          | -0.0233         |
|                   | 1990 | 1             | 1               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
| Tritium           | 1986 | 33            | 33              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                   | 1987 | 8             | 8               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                   | 1989 | 9             | 0               | 0                 | 9               | 1.00                | -240.000        | 70.0000         | -81.1111        |
|                   | 1990 | 15            | 4               | 0                 | 11              | 0.73                | -20.0000        | 418.0000        | 172.1157        |
| Uranium-233,-234  | 1986 | 33            | 33              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                   | 1987 | 9             | 9               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                   | 1989 | 31            | 1               | 0                 | 30              | 0.97                | -0.1100         | 0.5800          | 0.2610          |
|                   | 1990 | 29            | 3               | 0                 | 26              | 0.90                | -0.0200         | 1.4300          | 0.2848          |
| Uranium-235       | 1987 | 9             | 9               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                   | 1989 | 33            | 3               | 0                 | 30              | 0.91                | -0.1600         | 0.3700          | 0.0773          |
|                   | 1990 | 11            | 2               | 0                 | 9               | 0.82                | -0.0600         | 0.1100          | 0.0356          |
| Uranium-235/236   | 1990 | 18            | 1               | 0                 | 17              | 0.94                | 0.0000          | 0.8740          | 0.1706          |
| Uranium-238       | 1986 | 33            | 33              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                   | 1987 | 9             | 9               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                   | 1989 | 33            | 3               | 0                 | 30              | 0.91                | -0.1600         | 0.4700          | 0.1913          |
|                   | 1990 | 31            | 3               | 0                 | 28              | 0.90                | 0.0000          | 1.8900          | 0.2629          |

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TABLE 2-6 SUMMARY OF TRIP-BLANK RESULTS FOR DISSOLVED AND TOTAL RADIONUCLIDES BY YEAR

| Analyte                            | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration   |                 |                 |
|------------------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|-----------------|-----------------|-----------------|
|                                    |      |               |                 |                   |                 |                     | Minimum (pCi/L) | Maximum (pCi/L) | Average (pCi/L) |
| DISSOLVED                          |      |               |                 |                   |                 |                     |                 |                 |                 |
| Americium-241                      | 1987 | 18            | 18              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 40            | 22              | 0                 | 18              | 0.45                | 0.0000          | 0.0200          | 0.0067          |
|                                    | 1989 | 19            | 0               | 0                 | 19              | 1.00                | -0.0800         | 0.0500          | 0.0161          |
| Gross alpha particle radioactivity | 1987 | 20            | 20              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 42            | 24              | 0                 | 18              | 0.43                | -3.0000         | 2.0000          | -0.0556         |
|                                    | 1989 | 51            | 0               | 0                 | 51              | 1.00                | -0.5000         | 5.9000          | 0.8824          |
| Gross beta particle radioactivity  | 1987 | 20            | 20              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 42            | 24              | 0                 | 18              | 0.43                | -4.0000         | 6.0000          | 0.4444          |
|                                    | 1989 | 51            | 0               | 0                 | 51              | 1.00                | -2.2000         | 11.7000         | 2.5765          |
| Plutonium-239/240                  | 1987 | 19            | 19              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 42            | 24              | 0                 | 18              | 0.43                | -0.0100         | 0.0600          | 0.0044          |
|                                    | 1989 | 27            | 0               | 0                 | 27              | 1.00                | -0.0200         | 0.0300          | 0.0082          |
| Strontium-89,90                    | 1987 | 19            | 19              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 2             | 2               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1989 | 1             | 0               | 0                 | 1               | 1.00                | 0.0090          | 0.0090          | 0.0090          |
| Tritium                            | 1987 | 20            | 20              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 41            | 24              | 0                 | 17              | 0.41                | 190.0000        | 240.0000        | 217.0588        |
|                                    | 1989 | 29            | 0               | 0                 | 29              | 1.00                | 220.0000        | 270.0000        | 252.7586        |
| Uranium-233,-234                   | 1987 | 19            | 19              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 42            | 24              | 0                 | 18              | 0.43                | 0.0000          | 0.3000          | 0.0578          |
|                                    | 1989 | 29            | 0               | 0                 | 29              | 1.00                | -0.0300         | 3.6600          | 0.8117          |
| Uranium-235                        | 1987 | 19            | 19              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 42            | 24              | 0                 | 18              | 0.43                | 0.0000          | 0.3000          | 0.0222          |
|                                    | 1989 | 29            | 0               | 0                 | 29              | 1.00                | -0.1200         | 0.3800          | 0.1331          |
| Uranium-238                        | 1987 | 19            | 19              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1988 | 42            | 24              | 0                 | 18              | 0.43                | 0.0000          | 0.4000          | 0.0594          |
|                                    | 1989 | 29            | 0               | 0                 | 29              | 1.00                | -0.0700         | 0.5000          | 0.1493          |
| TOTAL                              |      |               |                 |                   |                 |                     |                 |                 |                 |
| Americium-241                      | 1986 | 33            | 33              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1987 | 22            | 22              | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                    | 1989 | 9             | 2               | 0                 | 7               | 0.78                | -0.0010         | 0.0220          | 0.0110          |

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TABLE 2-6 (cont.)

| Analyte                            | Year | Total<br>Samples | Number<br>Rejected | Number<br>Undetected | Number<br>Detected | Detection<br>Frequency | Concentration      |                    |                    |
|------------------------------------|------|------------------|--------------------|----------------------|--------------------|------------------------|--------------------|--------------------|--------------------|
|                                    |      |                  |                    |                      |                    |                        | Minimum<br>(pCi/L) | Maximum<br>(pCi/L) | Average<br>(pCi/L) |
| TOTAL (cont.)                      |      |                  |                    |                      |                    |                        |                    |                    |                    |
| Gross alpha particle radioactivity | 1986 | 33               | 33                 | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
|                                    | 1987 | 21               | 21                 | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
| Gross beta particle radioactivity  | 1986 | 33               | 33                 | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
|                                    | 1987 | 21               | 21                 | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
| Plutonium-239                      | 1989 | 15               | 0                  | 0                    | 15                 | 1.00                   | -0.0010            | 0.0300             | 0.0093             |
| Plutonium-239/240                  | 1986 | 33               | 0                  | 0                    | 33                 | 1.00                   | -0.2300            | 0.1200             | -0.0173            |
|                                    | 1987 | 22               | 0                  | 0                    | 22                 | 1.00                   | 0.0000             | 0.7100             | 0.0827             |
|                                    | 1989 | 3                | 0                  | 0                    | 3                  | 1.00                   | 0.0060             | 0.0080             | 0.0067             |
| Strontium-89,90                    | 1987 | 22               | 0                  | 0                    | 22                 | 1.00                   | 0.0600             | 1.4300             | 0.7318             |
| Strontium-90                       | 1989 | 1                | 0                  | 0                    | 1                  | 1.00                   | 0.0090             | 0.0090             | 0.0090             |
| Tritium                            | 1986 | 33               | 33                 | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
|                                    | 1987 | 21               | 21                 | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
| Uranium-233,-234                   | 1986 | 33               | 33                 | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
|                                    | 1987 | 22               | 22                 | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
|                                    | 1989 | 21               | 0                  | 0                    | 21                 | 1.00                   | 0.0600             | 0.9600             | 0.2214             |
| Uranium-235                        | 1987 | 22               | 22                 | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
|                                    | 1989 | 21               | 0                  | 0                    | 21                 | 1.00                   | -0.1200            | 0.1500             | 0.0505             |
| Uranium-238                        | 1986 | 33               | 33                 | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
|                                    | 1987 | 22               | 22                 | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
|                                    | 1989 | 21               | 0                  | 0                    | 21                 | 1.00                   | -0.0900            | 0.4800             | 0.1314             |

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**TABLE 2-7 SUMMARY OF EQUIPMENT-RINSATE-BLANK RESULTS FOR  
DISSOLVED AND TOTAL RADIONUCLIDES BY YEAR**

| Analyte                            | Year | Total<br>Samples | Number<br>Rejected | Number<br>Undetected | Number<br>Detected | Detection<br>Frequency | Concentration      |                    |                    |
|------------------------------------|------|------------------|--------------------|----------------------|--------------------|------------------------|--------------------|--------------------|--------------------|
|                                    |      |                  |                    |                      |                    |                        | Minimum<br>(pCi/L) | Maximum<br>(pCi/L) | Average<br>(pCi/L) |
| DISSOLVED                          |      |                  |                    |                      |                    |                        |                    |                    |                    |
| Cesium-137                         | 1992 | 5                | 0                  | 0                    | 5                  | 1.00                   | 0.0000             | 0.0000             | 0.0000             |
| Gross alpha-dissolved              | 1990 | 23               | 1                  | 0                    | 22                 | 0.96                   | -0.1130            | 40.6600            | 1.9589             |
|                                    | 1991 | 65               | 4                  | 0                    | 61                 | 0.94                   | -0.1320            | 0.2288             | 0.0383             |
|                                    | 1992 | 54               | 7                  | 0                    | 47                 | 0.87                   | -0.0560            | 1.2000             | 0.0834             |
| Gross alpha-suspended              | 1990 | 2                | 2                  | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
|                                    | 1992 | 7                | 0                  | 0                    | 7                  | 1.00                   | 0.0000             | 0.0000             | 0.0000             |
| Gross alpha particle radioactivity | 1990 | 1                | 0                  | 0                    | 1                  | 1.00                   | 0.2220             | 0.2220             | 0.2220             |
| Gross beta-dissolved               | 1990 | 23               | 1                  | 0                    | 22                 | 0.96                   | -0.1900            | 35.7800            | 2.0960             |
|                                    | 1991 | 63               | 3                  | 0                    | 60                 | 0.95                   | -0.4180            | 2.4700             | 0.4837             |
|                                    | 1992 | 54               | 5                  | 0                    | 49                 | 0.91                   | -0.1930            | 0.9258             | 0.3772             |
| Gross beta-suspended               | 1990 | 2                | 2                  | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
|                                    | 1992 | 7                | 0                  | 0                    | 7                  | 1.00                   | 0.0000             | 0.0000             | 0.0000             |
| Gross beta particle radioactivity  | 1990 | 1                | 1                  | 0                    | 0                  | 0.00                   | 0.0000             | 0.0000             | 0.0000             |
| Radium-226                         | 1990 | 1                | 0                  | 0                    | 1                  | 1.00                   | 4.3380             | 4.3380             | 4.3380             |
|                                    | 1992 | 5                | 0                  | 0                    | 5                  | 1.00                   | 0.1600             | 0.2400             | 0.2000             |
| Radium-228                         | 1990 | 1                | 0                  | 0                    | 1                  | 1.00                   | 6.6670             | 6.6670             | 6.6670             |
|                                    | 1992 | 5                | 0                  | 0                    | 5                  | 1.00                   | 2.6000             | 3.3000             | 2.9500             |

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**TABLE 2-7 (cont.)**

| Analyte           | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration   |                 |                 |
|-------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|-----------------|-----------------|-----------------|
|                   |      |               |                 |                   |                 |                     | Minimum (pCi/L) | Maximum (pCi/L) | Average (pCi/L) |
| DISSOLVED (cont.) |      |               |                 |                   |                 |                     |                 |                 |                 |
| Strontium-89      | 1990 | 2             | 2               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
| Strontium-89,90   | 1990 | 25            | 2               | 0                 | 23              | 0.92                | 0.1220          | 2.8490          | 0.4405          |
|                   | 1991 | 62            | 1               | 0                 | 61              | 0.98                | -0.1900         | 0.7603          | 0.2836          |
|                   | 1992 | 61            | 0               | 0                 | 61              | 1.00                | -0.0899         | 0.7547          | 0.2731          |
| Strontium-90      | 1990 | 2             | 2               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
| Total Radiocesium | 1990 | 2             | 2               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                   | 1992 | 11            | 0               | 0                 | 11              | 1.00                | 0.6100          | 0.6100          | 0.6100          |
| Tritium           | 1990 | 20            | 0               | 0                 | 20              | 1.00                | -212.000        | 7418.000        | 405.7445        |
|                   | 1991 | 54            | 1               | 0                 | 53              | 0.98                | -197.000        | 217.2000        | 28.7977         |
|                   | 1992 | 42            | 0               | 0                 | 42              | 1.00                | -238.000        | 202.1000        | -7.7546         |
| Uranium-233,-234  | 1990 | 28            | 2               | 0                 | 26              | 0.93                | -0.0116         | 36.1600         | 1.4391          |
|                   | 1991 | 61            | 1               | 0                 | 60              | 0.98                | -0.0374         | 0.3830          | 0.0689          |
|                   | 1992 | 60            | 5               | 0                 | 55              | 0.92                | -0.0215         | 0.8600          | 0.1351          |
| Uranium-235       | 1990 | 25            | 1               | 0                 | 24              | 0.96                | -0.0207         | 1.5160          | 0.0737          |
|                   | 1991 | 61            | 1               | 0                 | 60              | 0.98                | -0.0347         | 0.1281          | 0.0134          |
|                   | 1992 | 60            | 5               | 0                 | 55              | 0.92                | -0.0217         | 0.2600          | 0.0229          |
| Uranium-235/236   | 1990 | 3             | 1               | 0                 | 2               | 0.67                | -0.0100         | -0.0100         | -0.0100         |

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**TABLE 2-7 (cont.)**

| Analyte                            | Year | Total<br>Samples | Number<br>Rejected | Number<br>Undetected | Number<br>Detected | Detection<br>Frequency | Concentration      |                    |                    |
|------------------------------------|------|------------------|--------------------|----------------------|--------------------|------------------------|--------------------|--------------------|--------------------|
|                                    |      |                  |                    |                      |                    |                        | Minimum<br>(pCi/L) | Maximum<br>(pCi/L) | Average<br>(pCi/L) |
| DISSOLVED (cont.)                  |      |                  |                    |                      |                    |                        |                    |                    |                    |
| Uranium-238                        | 1990 | 28               | 2                  | 0                    | 26                 | 0.93                   | -0.0101            | 27.9800            | 1.1284             |
|                                    | 1991 | 61               | 1                  | 0                    | 60                 | 0.98                   | -0.0954            | 0.4251             | 0.0550             |
|                                    | 1992 | 60               | 5                  | 0                    | 55                 | 0.92                   | -0.0154            | 0.7300             | 0.0960             |
| TOTAL                              |      |                  |                    |                      |                    |                        |                    |                    |                    |
| Americium-241                      | 1990 | 43               | 2                  | 0                    | 41                 | 0.95                   | -0.0030            | 0.0276             | 0.0049             |
|                                    | 1991 | 62               | 8                  | 0                    | 54                 | 0.87                   | -0.0408            | 0.0448             | 0.0034             |
|                                    | 1992 | 61               | 1                  | 0                    | 60                 | 0.98                   | -0.0019            | 0.0140             | 0.0030             |
| Cesium-137                         | 1990 | 37               | 2                  | 0                    | 35                 | 0.95                   | -0.4200            | 358.9000           | 11.2109            |
|                                    | 1991 | 68               | 8                  | 0                    | 60                 | 0.88                   | -0.4570            | 0.9213             | 0.0294             |
|                                    | 1992 | 45               | 7                  | 0                    | 38                 | 0.84                   | -0.5280            | 0.7547             | 0.0396             |
| Gross alpha-dissolved              | 1990 | 6                | 0                  | 0                    | 6                  | 1.00                   | -0.1000            | 0.6000             | 0.2833             |
| Gross alpha-suspended              | 1990 | 6                | 5                  | 0                    | 1                  | 0.17                   | 1.5350             | 1.5350             | 1.5350             |
|                                    | 1992 | 1                | 0                  | 0                    | 1                  | 1.00                   | 0.0000             | 0.0000             | 0.0000             |
| Gross alpha particle radioactivity | 1990 | 2                | 0                  | 0                    | 2                  | 1.00                   | 0.0000             | 0.2370             | 0.1185             |
| Gross beta-dissolved               | 1990 | 6                | 0                  | 0                    | 6                  | 1.00                   | -0.3000            | -0.2000            | -0.2167            |
| Gross beta-suspended               | 1990 | 6                | 5                  | 0                    | 1                  | 0.17                   | 0.5375             | 0.5375             | 0.5375             |
|                                    | 1992 | 1                | 0                  | 0                    | 1                  | 1.00                   | 0.0000             | 0.0000             | 0.0000             |

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**TABLE 2-7 (cont.)**

| Analyte                           | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration   |                 |                 |
|-----------------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|-----------------|-----------------|-----------------|
|                                   |      |               |                 |                   |                 |                     | Minimum (pCi/L) | Maximum (pCi/L) | Average (pCi/L) |
| TOTAL (cont.)                     |      |               |                 |                   |                 |                     |                 |                 |                 |
| Gross beta particle radioactivity | 1990 | 2             | 0               | 0                 | 2               | 1.00                | -0.4260         | -0.2480         | -0.3370         |
| Plutonium-238                     | 1990 | 13            | 0               | 0                 | 13              | 1.00                | -0.0005         | 0.0132          | 0.0028          |
|                                   | 1991 | 1             | 0               | 0                 | 1               | 1.00                | 0.0000          | 0.0000          | 0.0000          |
| Plutonium-239/240                 | 1990 | 39            | 4               | 0                 | 35              | 0.90                | -0.0020         | 0.0322          | 0.0025          |
|                                   | 1991 | 62            | 1               | 0                 | 61              | 0.98                | -0.0007         | 0.0664          | 0.0024          |
|                                   | 1992 | 61            | 2               | 0                 | 59              | 0.97                | -0.0011         | 0.0944          | 0.0038          |
| Strontium-89                      | 1990 | 1             | 1               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
| Strontium-89,90                   | 1990 | 8             | 2               | 0                 | 6               | 0.75                | -0.0200         | 0.1100          | 0.0400          |
|                                   | 1992 | 1             | 0               | 0                 | 1               | 1.00                | 0.0000          | 0.0000          | 0.0000          |
| Strontium-90                      | 1990 | 7             | 1               | 0                 | 6               | 0.86                | -0.1578         | 0.1090          | -0.0347         |
| Total Radiocesium                 | 1990 | 1             | 1               | 0                 | 0               | 0.00                | 0.0000          | 0.0000          | 0.0000          |
|                                   | 1992 | 1             | 0               | 0                 | 1               | 1.00                | 1.3000          | 1.3000          | 1.3000          |
| Tritium                           | 1990 | 12            | 6               | 0                 | 6               | 0.50                | -160.000        | 50.0000         | -13.5000        |
|                                   | 1992 | 19            | 0               | 0                 | 19              | 1.00                | -2.7900         | 390.0000        | 193.6050        |
| Uranium-233,-234                  | 1990 | 11            | 0               | 0                 | 11              | 1.00                | 0.0000          | 0.4000          | 0.1931          |
|                                   | 1992 | 1             | 0               | 0                 | 1               | 1.00                | 0.9600          | 0.9600          | 0.9600          |
| Uranium-235                       | 1992 | 1             | 0               | 0                 | 1               | 1.00                | 0.2000          | 0.2000          | 0.2000          |
| Uranium-235/236                   | 1990 | 11            | 0               | 0                 | 11              | 1.00                | -0.0100         | 0.2360          | 0.0571          |
| Uranium-238                       | 1990 | 11            | 0               | 0                 | 11              | 1.00                | 0.0000          | 0.2110          | 0.0975          |
|                                   | 1992 | 1             | 0               | 0                 | 1               | 1.00                | 0.9800          | 0.9800          | 0.9800          |

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**TABLE 2-8 RELATIVE PERCENT DIFFERENCE FOR DISSOLVED  
AND TOTAL RADIONUCLIDES IN FIELD DUPLICATES**

| Analyte                            | Number of Duplicate Samples | Relative Percent Difference |         |         |
|------------------------------------|-----------------------------|-----------------------------|---------|---------|
|                                    |                             | Minimum                     | Maximum | Average |
| DISSOLVED                          |                             |                             |         |         |
| Americium-241                      | 37                          | 0                           | 200     | 69      |
| Cesium-137                         | 21                          | 0                           | 200     | 89      |
| Gross alpha-dissolved              | 121                         | 1                           | 179     | 56      |
| Gross alpha-suspended              | 8                           | 6                           | 200     | 65      |
| Gross alpha particle radioactivity | 59                          | 0                           | 200     | 72      |
| Gross beta-dissolved               | 125                         | 1                           | 191     | 45      |
| Gross beta-suspended               | 10                          | 3                           | 136     | 61      |
| Gross beta particle radioactivity  | 56                          | 0                           | 200     | 53      |
| Plutonium-239                      | 8                           | 11                          | 135     | 59      |
| Plutonium-239/240                  | 38                          | 0                           | 200     | 71      |
| Radium-226                         | 15                          | 0                           | 59      | 21      |
| Radium-228                         | 6                           | 4                           | 58      | 27      |
| Strontium-89,90                    | 146                         | 0                           | 200     | 64      |
| Strontium-90                       | 7                           | 8                           | 168     | 68      |
| Total radiocesium                  | 10                          | 1                           | 107     | 27      |
| Tritium                            | 128                         | 0                           | 197     | 45      |
| Uranium-233,-234                   | 184                         | 0                           | 200     | 41      |
| Uranium-235                        | 124                         | 0                           | 200     | 69      |
| Uranium-238                        | 175                         | 0                           | 200     | 47      |
| TOTAL                              |                             |                             |         |         |
| Americium-241                      | 154                         | 0                           | 200     | 86      |
| Cesium                             | 2                           | 0                           | 200     | 100     |
| Cesium-137                         | 39                          | 3                           | 183     | 74      |
| Gross alpha-dissolved              | 6                           | 0                           | 187     | 125     |
| Gross alpha-suspended              | 10                          | 14                          | 116     | 55      |
| Gross alpha particle radioactivity | 2                           | 24                          | 90      | 57      |
| Gross beta-dissolved               | 5                           | 86                          | 182     | 133     |
| Gross beta-suspended               | 4                           | 10                          | 51      | 23      |
| Gross beta particle radioactivity  | 4                           | 0                           | 93      | 44      |
| Plutonium-238                      | 7                           | 0                           | 200     | 101     |
| Plutonium-239/240                  | 138                         | 0                           | 200     | 96      |

TABLE 2-8. (cont.)

| Analyte         | Number of Duplicate Samples | Relative Percent Difference |         |         |
|-----------------|-----------------------------|-----------------------------|---------|---------|
|                 |                             | Minimum                     | Maximum | Average |
| TOTAL (cont.)   |                             |                             |         |         |
| Radium-226      | 3                           | 23                          | 26      | 24      |
| Strontium-89,90 | 11                          | 0                           | 200     | 99      |
| Strontium-90    | 4                           | 77                          | 195     | 144     |
|                 |                             |                             |         |         |
| Uranium-235     | 4                           | 18                          | 200     | 92      |
| Uranium-235/236 | 12                          | 0                           | 200     | 83      |
| Uranium-238     | 21                          | 0                           | 200     | 43      |

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TABLE 2-9 SUMMARY OF FIELD-BLANK RESULTS FOR WATER-QUALITY PARAMETERS BY YEAR

| Analyte                          | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|----------------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                                  |      |               |                 |                   |                 |                     | Minimum (mg/L) | Maximum (mg/L) | Average (mg/L) |
| Bicarbonate                      | 1987 | 29            | 0               | 25                | 4               | 0.14                | 1.5000         | 2.6300         | 1.9825         |
|                                  | 1988 | 55            | 0               | 46                | 9               | 0.16                | 0.5200         | 314.0000       | 39.4956        |
|                                  | 1989 | 72            | 0               | 71                | 1               | 0.01                | 1.0000         | 1.0000         | 1.0000         |
|                                  | 1990 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Bicarbonate as CaCO <sub>3</sub> | 1990 | 23            | 0               | 3                 | 20              | 0.87                | 1.0000         | 10.0000        | 2.9000         |
| Carbonate                        | 1987 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1989 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1990 | 7             | 0               | 7                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Carbonate as CaCO <sub>3</sub>   | 1990 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Chloride                         | 1986 | 33            | 0               | 15                | 18              | 0.55                | 0.4000         | 14.0000        | 1.4717         |
|                                  | 1987 | 29            | 0               | 26                | 3               | 0.10                | 0.4900         | 1.0000         | 0.7267         |
|                                  | 1988 | 55            | 0               | 27                | 28              | 0.51                | 0.3700         | 40.4000        | 9.8429         |
|                                  | 1989 | 72            | 0               | 71                | 1               | 0.01                | 2.0000         | 2.0000         | 2.0000         |
|                                  | 1990 | 24            | 0               | 9                 | 15              | 0.63                | 0.3000         | 1.6000         | 0.7667         |
| Cyanide                          | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1987 | 21            | 0               | 21                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1989 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1990 | 2             | 0               | 2                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Cyanides (soluble salts and CO)  | 1990 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Fluoride                         | 1990 | 18            | 0               | 18                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Fluoride, soluble                | 1990 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Hexavalent chromium              | 1986 | 23            | 0               | 23                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Nitrate                          | 1990 | 3             | 0               | 3                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Nitrate/nitrite                  | 1986 | 22            | 0               | 19                | 3               | 0.14                | 7.7000         | 55.0000        | 31.0333        |
|                                  | 1987 | 29            | 0               | 29                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1988 | 55            | 1               | 18                | 36              | 0.65                | 0.0200         | 2.3000         | 0.2917         |
|                                  | 1989 | 73            | 0               | 64                | 9               | 0.12                | 0.0200         | 1.1600         | 0.1700         |
|                                  | 1990 | 21            | 0               | 19                | 2               | 0.10                | 0.0300         | 0.0300         | 0.0300         |
| Nitrite                          | 1990 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Oil and grease                   | 1989 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Orthophosphate                   | 1990 | 9             | 0               | 9                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Phosphate                        | 1986 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1990 | 18            | 0               | 18                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Phosphorus                       | 1990 | 3             | 0               | 3                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Silica, dissolved                | 1990 | 21            | 0               | 19                | 2               | 0.10                | 0.5000         | 4.0000         | 2.2500         |
| Silicon                          | 1990 | 2             | 0               | 2                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Sodium fluoride                  | 1990 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |

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**TABLE 2-9 (cont.)**

| Analyte                | Year | Total<br>Samples | Number<br>Rejected | Number<br>Undetected | Number<br>Detected | Detection<br>Frequency | Concentration     |                   |                   |
|------------------------|------|------------------|--------------------|----------------------|--------------------|------------------------|-------------------|-------------------|-------------------|
|                        |      |                  |                    |                      |                    |                        | Minimum<br>(mg/L) | Maximum<br>(mg/L) | Average<br>(mg/L) |
| Sodium sulfate         | 1990 | 1                | 0                  | 1                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Sulfate                | 1986 | 33               | 0                  | 26                   | 7                  | 0.21                   | 3.2000            | 7.0000            | 4.4714            |
|                        | 1987 | 29               | 0                  | 24                   | 5                  | 0.17                   | 0.5000            | 8.8000            | 3.9700            |
|                        | 1988 | 54               | 13                 | 23                   | 18                 | 0.33                   | 0.0300            | 2.8600            | 0.3133            |
|                        | 1989 | 72               | 0                  | 72                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                        | 1990 | 24               | 0                  | 24                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Total dissolved solids | 1986 | 33               | 0                  | 14                   | 19                 | 0.58                   | 12.0000           | 63.0000           | 27.7368           |
|                        | 1987 | 29               | 0                  | 2                    | 27                 | 0.93                   | 1.0000            | 29.0000           | 6.2963            |
|                        | 1988 | 51               | 5                  | 1                    | 45                 | 0.88                   | 1.0000            | 79.0000           | 12.9778           |
|                        | 1989 | 72               | 0                  | 60                   | 12                 | 0.17                   | 5.0000            | 23.0000           | 13.0000           |
|                        | 1990 | 25               | 0                  | 24                   | 1                  | 0.04                   | 16.0000           | 16.0000           | 16.0000           |
| Total suspended solids | 1989 | 6                | 0                  | 6                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                        | 1990 | 23               | 0                  | 23                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| pH                     | 1989 | 6                | 0                  | 0                    | 6                  | 1.00                   | 5.1000            | 5.2000            | 5.1667            |

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TABLE 2-10 SUMMARY OF TRIP-BLANK RESULTS FOR WATER-QUALITY PARAMETERS BY YEAR

| Analyte                | Date | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                        |      |               |                 |                   |                 |                     | Minimum (mg/L) | Maximum (mg/L) | Average (mg/L) |
| Bicarbonate            | 1986 | 33            | 0               | 23                | 10              | 0.30                | 4.9000         | 31.0000        | 10.5700        |
|                        | 1987 | 42            | 0               | 37                | 5               | 0.12                | 1.0300         | 2.6000         | 1.5780         |
|                        | 1988 | 55            | 0               | 49                | 6               | 0.11                | 0.3800         | 18.6000        | 8.8733         |
|                        | 1989 | 65            | 0               | 65                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Carbonate              | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                        | 1988 | 1             | 0               | 0                 | 1               | 1.00                | 0.0000         | 0.0000         | 0.0000         |
| Chloride               | 1986 | 33            | 0               | 12                | 21              | 0.64                | 0.0400         | 5.3000         | 0.8048         |
|                        | 1987 | 42            | 0               | 40                | 2               | 0.05                | 0.2700         | 0.6100         | 0.4400         |
|                        | 1988 | 55            | 1               | 25                | 29              | 0.53                | 0.2500         | 43.8000        | 8.7676         |
|                        | 1989 | 65            | 0               | 65                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Cyanide                | 1986 | 33            | 0               | 32                | 1               | 0.03                | 0.0090         | 0.0090         | 0.0090         |
|                        | 1987 | 34            | 0               | 34                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Nitrate/nitrite        | 1987 | 42            | 0               | 40                | 2               | 0.05                | 2.0700         | 2.2500         | 2.1600         |
|                        | 1988 | 55            | 1               | 17                | 37              | 0.67                | 0.0200         | 2.1000         | 0.2141         |
|                        | 1989 | 65            | 0               | 59                | 6               | 0.09                | 0.0200         | 1.8800         | 0.5083         |
| Phosphate              | 1986 | 33            | 0               | 28                | 5               | 0.15                | 0.7400         | 7.2000         | 2.2440         |
| Sulfate                | 1986 | 33            | 0               | 23                | 10              | 0.30                | 3.4000         | 9.2000         | 4.6500         |
|                        | 1987 | 42            | 0               | 35                | 7               | 0.17                | 0.5000         | 11.3000        | 3.4786         |
|                        | 1988 | 55            | 13              | 22                | 20              | 0.36                | 0.0400         | 0.7500         | 0.1885         |
|                        | 1989 | 65            | 0               | 65                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Total dissolved solids | 1986 | 33            | 0               | 14                | 19              | 0.58                | 10.0000        | 460.0000       | 44.5789        |
|                        | 1987 | 42            | 0               | 4                 | 38              | 0.90                | 1.0000         | 66.0000        | 8.0263         |
|                        | 1988 | 51            | 5               | 1                 | 45              | 0.88                | 1.0000         | 86.0000        | 14.9111        |
|                        | 1989 | 65            | 0               | 59                | 6               | 0.09                | 12.0000        | 36.0000        | 22.8333        |

TABLE 2-11 SUMMARY OF EQUIPMENT-RINSATE-BLANK RESULTS FOR WATER-QUALITY PARAMETERS BY YEAR

| Analyte                          | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|----------------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                                  |      |               |                 |                   |                 |                     | Minimum (mg/L) | Maximum (mg/L) | Average (mg/L) |
| Alkalinity as CaCO <sub>3</sub>  | 1992 | 2             | 0               | 2                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Ammonia                          | 1992 | 13            | 0               | 10                | 3               | 0.23                | 0.1300         | 0.3600         | 0.2200         |
| Bicarbonate                      | 1990 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Bicarbonate as CaCO <sub>3</sub> | 1990 | 25            | 0               | 4                 | 21              | 0.84                | 2.0000         | 19.0000        | 3.6667         |
|                                  | 1991 | 43            | 0               | 29                | 14              | 0.33                | 1.0000         | 195.0000       | 26.0000        |
|                                  | 1992 | 64            | 0               | 36                | 28              | 0.44                | 1.0000         | 33.0000        | 5.5714         |
| Carbonate                        | 1990 | 7             | 0               | 7                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1991 | 3             | 0               | 3                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1992 | 34            | 0               | 34                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Carbonate as CaCO <sub>3</sub>   | 1990 | 3             | 0               | 3                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1991 | 39            | 0               | 39                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1992 | 30            | 0               | 30                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Chemical oxygen demand           | 1992 | 8             | 0               | 5                 | 3               | 0.38                | 5.6000         | 16.0000        | 9.2000         |
| Chloride                         | 1990 | 26            | 0               | 9                 | 17              | 0.65                | 0.2000         | 4.2000         | 0.9235         |
|                                  | 1991 | 45            | 1               | 42                | 2               | 0.04                | 0.7000         | 48.0000        | 24.3500        |
|                                  | 1992 | 58            | 1               | 56                | 1               | 0.02                | 11.2000        | 11.2000        | 11.2000        |
| Cyanide                          | 1990 | 4             | 0               | 4                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1991 | 4             | 0               | 4                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1992 | 3             | 0               | 3                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Cyanides (soluble salts and CO)  | 1990 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1991 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1992 | 4             | 0               | 4                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Fluoride                         | 1990 | 20            | 0               | 20                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1991 | 41            | 0               | 41                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1992 | 44            | 0               | 42                | 2               | 0.05                | 0.1000         | 0.2000         | 0.1500         |
| Fluoride, soluble                | 1990 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1991 | 3             | 0               | 3                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1992 | 20            | 0               | 20                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Hydrocyanic acid                 | 1992 | 13            | 0               | 11                | 2               | 0.15                | 0.0130         | 0.0150         | 0.0140         |
| Nitrate                          | 1990 | 3             | 0               | 3                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1991 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Nitrate/nitrite                  | 1990 | 23            | 0               | 21                | 2               | 0.09                | 0.2000         | 0.7000         | 0.4500         |
|                                  | 1991 | 44            | 0               | 21                | 23              | 0.52                | 0.0200         | 0.3000         | 0.0778         |
|                                  | 1992 | 66            | 6               | 47                | 13              | 0.20                | 0.0300         | 0.3000         | 0.0754         |
| Nitrite                          | 1990 | 16            | 0               | 15                | 1               | 0.06                | 0.1000         | 0.1000         | 0.1000         |
|                                  | 1991 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                                  | 1992 | 1             | 0               | 1                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |

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**TABLE 2-11 (cont.)**

| Analyte                | Year | Total<br>Samples | Number<br>Rejected | Number<br>Undetected | Number<br>Detected | Detection<br>Frequency | Concentration     |                   |                   |
|------------------------|------|------------------|--------------------|----------------------|--------------------|------------------------|-------------------|-------------------|-------------------|
|                        |      |                  |                    |                      |                    |                        | Minimum<br>(mg/L) | Maximum<br>(mg/L) | Average<br>(mg/L) |
| Orthophosphate         | 1990 | 9                | 0                  | 9                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                        | 1991 | 41               | 0                  | 37                   | 4                  | 0.10                   | 0.0100            | 0.0400            | 0.0200            |
|                        | 1992 | 65               | 0                  | 65                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Phosphate              | 1990 | 18               | 0                  | 18                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                        | 1991 | 2                | 0                  | 2                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Phosphorus             | 1990 | 3                | 0                  | 2                    | 1                  | 0.33                   | 0.0280            | 0.0280            | 0.0280            |
| Silica, dissolved      | 1990 | 22               | 0                  | 20                   | 2                  | 0.09                   | 3.0000            | 30.2000           | 16.6000           |
|                        | 1991 | 40               | 0                  | 40                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                        | 1992 | 18               | 0                  | 16                   | 2                  | 0.11                   | 0.5000            | 0.6000            | 0.5500            |
| Silicon                | 1990 | 2                | 0                  | 2                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Sodium fluoride        | 1990 | 1                | 0                  | 1                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                        | 1991 | 1                | 0                  | 1                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Sodium sulfate         | 1990 | 1                | 0                  | 1                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                        | 1991 | 1                | 0                  | 1                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Sulfate                | 1990 | 25               | 0                  | 25                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                        | 1991 | 43               | 1                  | 33                   | 9                  | 0.21                   | 2.0000            | 6.0000            | 3.0889            |
|                        | 1992 | 58               | 0                  | 54                   | 4                  | 0.07                   | 2.0000            | 5.9000            | 2.9750            |
| Total dissolved solids | 1990 | 27               | 0                  | 23                   | 4                  | 0.15                   | 11.0000           | 32.0000           | 20.0000           |
|                        | 1991 | 45               | 0                  | 42                   | 3                  | 0.07                   | 10.0000           | 13.0000           | 12.0000           |
|                        | 1992 | 65               | 0                  | 55                   | 10                 | 0.15                   | 10.0000           | 270.0000          | 80.8000           |
| Total organic carbon   | 1992 | 12               | 0                  | 9                    | 3                  | 0.25                   | 1.0000            | 1.0500            | 1.0167            |
| Total solids           | 1992 | 4                | 0                  | 4                    | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| Total suspended solids | 1990 | 25               | 0                  | 25                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
|                        | 1991 | 44               | 0                  | 41                   | 3                  | 0.07                   | 6.0000            | 210.0000          | 75.0000           |
|                        | 1992 | 61               | 0                  | 61                   | 0                  | 0.00                   | 0.0000            | 0.0000            | 0.0000            |
| pH                     | 1992 | 2                | 0                  | 0                    | 2                  | 1.00                   | 6.2000            | 6.2000            | 6.2000            |

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**TABLE 2-12 RELATIVE PERCENT DIFFERENCE FOR WATER-QUALITY PARAMETERS IN FIELD DUPLICATES**

| Analyte                          | Number of Duplicate Samples | Relative Percent Difference |         |         |
|----------------------------------|-----------------------------|-----------------------------|---------|---------|
|                                  |                             | Minimum                     | Maximum | Average |
| Alkalinity as CaCO <sub>3</sub>  | 3                           | 0                           | 8       | 3       |
| Bicarbonate                      | 103                         | 0                           | 186     | 8       |
| Bicarbonate as CaCO <sub>3</sub> | 137                         | 0                           | 118     | 6       |
| Carbonate                        | 4                           | 0                           | 32      | 8       |
| Carbonate as CaCO <sub>3</sub>   | 19                          | 0                           | 0       | 0       |
| Chemical oxygen demand           | 3                           | 12                          | 22      | 16      |
| Chloride                         | 230                         | 0                           | 192     | 9       |
| Cyanide                          | 4                           | 0                           | 18      | 7       |
| Fluoride                         | 115                         | 0                           | 173     | 9       |
| Fluoride, soluble                | 25                          | 0                           | 33      | 8       |
| Nitrate                          | 4                           | 0                           | 33      | 11      |
| Nitrate/nitrite                  | 225                         | 0                           | 199     | 13      |
| Nitrite                          | 2                           | 0                           | 25      | 13      |
| Oil and grease                   | 2                           | 0                           | 0       | 0       |
| Orthophosphate                   | 30                          | 0                           | 143     | 26      |
| Phosphate                        | 13                          | 0                           | 155     | 43      |
| Phosphorus                       | 1                           | 74                          | 74      | 74      |
| Silica, dissolved                | 76                          | 0                           | 111     | 4       |
| Silicon                          | 2                           | 0                           | 6       | 3       |
| Sodium fluoride                  | 1                           | 0                           | 0       | 0       |
| Sodium sulfate                   | 1                           | 8                           | 8       | 8       |
| Solids, nonvolatile suspended    | 2                           | 11                          | 76      | 43      |
| Sulfate                          | 238                         | 0                           | 164     | 10      |
| Total dissolved solids           | 260                         | 0                           | 195     | 11      |
| Total organic carbon             | 12                          | 0                           | 64      | 19      |
| Total solids                     | 4                           | 9                           | 108     | 55      |
| Total suspended solids           | 150                         | 0                           | 199     | 47      |
| pH                               | 61                          | 0                           | 5       | 1       |

**TABLE 2-13 SUMMARY OF RELATIVE PERCENT DIFFERENCE  
FOR SEMIVOLATILE ABN COMPOUNDS IN FIELD DUPLICATES**

| Analyte                    | Number of<br>Duplicate<br>Samples | Relevant Percent Difference |         |         |
|----------------------------|-----------------------------------|-----------------------------|---------|---------|
|                            |                                   | Minimum                     | Maximum | Average |
| Benzoic acid               | 1                                 | 11                          | 11      | 11      |
| Bis(2-ethylhexyl)phthalate | 1                                 | 109                         | 109     | 109     |

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TABLE 2-14 SUMMARY OF FIELD-BLANK RESULTS FOR VOLATILE ORGANIC COMPOUNDS BY YEAR

| Analyte                   | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|---------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                           |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| 1,1,1-Trichloroethane     | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 83            | 0               | 82                | 1               | 0.01                | 5.0000         | 5.0000         | 5.0000         |
|                           | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,1,2,2-Tetrachloroethane | 1986 | 33            | 0               | 32                | 1               | 0.03                | 1.0000         | 1.0000         | 1.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,1,2-Trichloroethane     | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 36            | 0               | 35                | 1               | 0.03                | 1.0000         | 1.0000         | 1.0000         |
| 1,1-Dichloroethane        | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 55            | 10              | 45                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 36            | 1               | 35                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,1-Dichloroethene        | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,2-Dichloroethane        | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 28            | 0               | 26                | 2               | 0.07                | 16.0000        | 18.0000        | 17.0000        |
|                           | 1988 | 55            | 10              | 45                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 83            | 1               | 82                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 36            | 0               | 35                | 1               | 0.03                | 1.0000         | 1.0000         | 1.0000         |
| 1,2-Dichloroethene        | 1987 | 24            | 0               | 24                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 35            | 0               | 35                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,2-Dichloropropane       | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |

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**TABLE 2-14. (cont.)**

| Analyte                   | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|---------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                           |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| 1,2-Dimethylbenzene       | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 4             | 0               | 4                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 2-Butanone                | 1986 | 33            | 3               | 25                | 5               | 0.15                | 4.0000         | 9.0000         | 6.4000         |
|                           | 1987 | 6             | 0               | 3                 | 3               | 0.50                | 19.0000        | 40.0000        | 30.0000        |
|                           | 1988 | 55            | 14              | 31                | 10              | 0.18                | 4.0000         | 34.0000        | 17.7000        |
|                           | 1989 | 83            | 22              | 47                | 14              | 0.17                | 2.0000         | 26.0000        | 11.5714        |
|                           | 1990 | 36            | 6               | 29                | 1               | 0.03                | 5.0000         | 5.0000         | 5.0000         |
| 2-Chloroethyl vinyl ether | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 4             | 0               | 4                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 38            | 0               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 50            | 0               | 50                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 4             | 0               | 4                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 2-Hexanone                | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 83            | 2               | 81                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 4-Methyl-2-pentanone      | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 83            | 3               | 80                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Acetone                   | 1986 | 33            | 13              | 5                 | 15              | 0.45                | 1.0000         | 67.0000        | 18.7333        |
|                           | 1987 | 6             | 1               | 4                 | 1               | 0.17                | 16.0000        | 16.0000        | 16.0000        |
|                           | 1988 | 55            | 9               | 39                | 7               | 0.13                | 3.0000         | 26.0000        | 9.2857         |
|                           | 1989 | 83            | 3               | 62                | 18              | 0.22                | 3.0000         | 45.0000        | 10.1111        |
|                           | 1990 | 36            | 4               | 14                | 18              | 0.50                | 3.0000         | 42.0000        | 14.4444        |
| Benzene                   | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Bromodichloromethane      | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |

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**TABLE 2-14 (cont.)**

| Analyte              | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|----------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                      |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| Bromoform            | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Bromomethane         | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 16              | 39                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 83            | 3               | 80                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Carbon disulfide     | 1986 | 33            | 0               | 24                | 9               | 0.27                | 1.0000         | 5.0000         | 3.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 11              | 44                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 83            | 3               | 79                | 1               | 0.01                | 2.0000         | 2.0000         | 2.0000         |
|                      | 1990 | 36            | 0               | 35                | 1               | 0.03                | 5.0000         | 5.0000         | 5.0000         |
| Carbon tetrachloride | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 28            | 0               | 27                | 1               | 0.04                | 6.0000         | 6.0000         | 6.0000         |
|                      | 1988 | 55            | 9               | 45                | 1               | 0.02                | 8.0000         | 8.0000         | 8.0000         |
|                      | 1989 | 83            | 0               | 81                | 2               | 0.02                | 18.0000        | 87.0000        | 52.5000        |
|                      | 1990 | 36            | 0               | 35                | 1               | 0.03                | 1.0000         | 1.0000         | 1.0000         |
| Chlorobenzene        | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Chloroethane         | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 21              | 34                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 83            | 1               | 82                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Chloroform           | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 19              | 35                | 1               | 0.02                | 2.0000         | 2.0000         | 2.0000         |
|                      | 1989 | 83            | 0               | 80                | 3               | 0.04                | 2.0000         | 3.0000         | 2.6667         |
|                      | 1990 | 36            | 0               | 33                | 3               | 0.08                | 9.0000         | 20.0000        | 13.6667        |
| Chloromethane        | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 18              | 37                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 83            | 5               | 78                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |

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*Groundwater Geochemistry of Rocky Flats Plant*

**TABLE 2-14. (cont.)**

| Analyte              | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|----------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                      |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| Dibromochloromethane | 1990 | 36            | 0               | 35                | 1               | 0.03                | 3.0000         | 3.0000         | 3.0000         |
|                      | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Ethylbenzene         | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Methylene chloride   | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1986 | 33            | 1               | 14                | 18              | 0.55                | 1.0000         | 260.0000       | 17.8333        |
|                      | 1987 | 6             | 1               | 0                 | 5               | 0.83                | 4.0000         | 64.0000        | 29.4000        |
|                      | 1988 | 55            | 12              | 16                | 27              | 0.49                | 2.0000         | 65.0000        | 13.6667        |
|                      | 1989 | 83            | 3               | 38                | 42              | 0.51                | 2.0000         | 16.0000        | 7.3095         |
| Styrene              | 1990 | 37            | 12              | 13                | 12              | 0.32                | 1.0000         | 14.0000        | 5.5833         |
|                      | 1986 | 33            | 0               | 32                | 1               | 0.03                | 4.0000         | 4.0000         | 4.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Tetrachloroethene    | 1990 | 36            | 0               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 83            | 0               | 80                | 3               | 0.04                | 2.0000         | 2.0000         | 2.0000         |
| Toluene              | 1990 | 36            | 0               | 35                | 1               | 0.03                | 12.0000        | 12.0000        | 12.0000        |
|                      | 1986 | 33            | 2               | 27                | 4               | 0.12                | 1.0000         | 2.0000         | 1.2500         |
|                      | 1987 | 6             | 0               | 5                 | 1               | 0.17                | 12.0000        | 12.0000        | 12.0000        |
|                      | 1988 | 55            | 19              | 35                | 1               | 0.02                | 5.0000         | 5.0000         | 5.0000         |
|                      | 1989 | 83            | 1               | 81                | 1               | 0.01                | 4.0000         | 4.0000         | 4.0000         |
| Total xylenes        | 1990 | 36            | 1               | 30                | 5               | 0.14                | 1.0000         | 3.0000         | 1.8000         |
|                      | 1986 | 33            | 0               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 9               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 83            | 0               | 83                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Trichloroethene      | 1990 | 36            | 1               | 35                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1986 | 33            | 0               | 30                | 3               | 0.09                | 2.0000         | 3.0000         | 2.6667         |
|                      | 1987 | 28            | 0               | 28                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 55            | 9               | 44                | 2               | 0.04                | 4.0000         | 8.0000         | 6.0000         |

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TABLE 2-14. (cont.)

| Analyte                   | Year | Total<br>Samples | Number<br>Rejected | Number<br>Undetected | Number<br>Detected | Detection<br>Frequency | Concentration                  |                                |                                |
|---------------------------|------|------------------|--------------------|----------------------|--------------------|------------------------|--------------------------------|--------------------------------|--------------------------------|
|                           |      |                  |                    |                      |                    |                        | Minimum<br>( $\mu\text{g/L}$ ) | Maximum<br>( $\mu\text{g/L}$ ) | Average<br>( $\mu\text{g/L}$ ) |
| Vinyl acetate             | 1989 | 83               | 0                  | 77                   | 6                  | 0.07                   | 2.0000                         | 39.0000                        | 11.6667                        |
|                           | 1990 | 36               | 0                  | 34                   | 2                  | 0.06                   | 2.0000                         | 2.0000                         | 2.0000                         |
|                           | 1986 | 33               | 0                  | 33                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1987 | 6                | 0                  | 6                    | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1988 | 55               | 9                  | 46                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1989 | 83               | 6                  | 77                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
| Vinyl chloride            | 1990 | 36               | 0                  | 36                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1986 | 33               | 0                  | 33                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1987 | 6                | 0                  | 6                    | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1988 | 55               | 9                  | 46                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1989 | 83               | 6                  | 77                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1990 | 36               | 0                  | 36                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
| cis-1,3-Dichloropropene   | 1986 | 33               | 0                  | 33                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1987 | 6                | 0                  | 6                    | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1988 | 55               | 9                  | 46                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1989 | 83               | 0                  | 83                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1990 | 36               | 0                  | 36                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1986 | 33               | 0                  | 33                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
| trans-1,2-Dichloroethene  | 1987 | 4                | 0                  | 4                    | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1989 | 49               | 0                  | 49                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1990 | 1                | 0                  | 1                    | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1986 | 33               | 0                  | 33                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1987 | 6                | 0                  | 6                    | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1988 | 55               | 9                  | 46                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
| trans-1,3-Dichloropropene | 1989 | 83               | 0                  | 83                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |
|                           | 1990 | 36               | 0                  | 36                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.0000                         |

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TABLE 2-15 SUMMARY OF TRIP-BLANK RESULTS FOR VOLATILE ORGANIC COMPOUNDS BY YEAR

| Analyte                   | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|---------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                           |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| 1,1,1-Trichloroethane     | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 43            | 0               | 43                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 190           | 0               | 187               | 3               | 0.02                | 1.0000         | 38.0000        | 16.6667        |
|                           | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,1,2,2-Tetrachloroethane | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 227           | 0               | 227               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,1,2-Trichloroethane     | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 43            | 0               | 43                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,1-Dichloroethane        | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 10              | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,1-Dichloroethene        | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 43            | 0               | 43                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 46                | 1               | 0.02                | 4.0000         | 4.0000         | 4.0000         |
|                           | 1989 | 190           | 0               | 189               | 1               | 0.01                | 2.0000         | 2.0000         | 2.0000         |
|                           | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,2-Dichloroethane        | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 43            | 0               | 41                | 2               | 0.05                | 18.0000        | 32.0000        | 25.0000        |
|                           | 1988 | 56            | 10              | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 190           | 1               | 189               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,2-Dichloroethene        | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 39            | 0               | 39                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 231           | 0               | 231               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 1,2-Dichloropropane       | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |

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TABLE 2-15 (cont.)

| Analyte                   | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|---------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                           |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| 1,2-Dimethylbenzene       | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 4             | 0               | 4                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 2-Butanone                | 1986 | 32            | 2               | 24                | 6               | 0.19                | 1.0000         | 10.0000        | 6.3333         |
|                           | 1987 | 6             | 0               | 3                 | 3               | 0.50                | 13.0000        | 49.0000        | 28.6667        |
|                           | 1988 | 56            | 16              | 30                | 10              | 0.18                | 5.0000         | 32.0000        | 13.3000        |
|                           | 1989 | 190           | 36              | 126               | 28              | 0.15                | 3.0000         | 220.0000       | 42.6071        |
| 2-Chloroethyl vinyl ether | 1990 | 233           | 8               | 215               | 10              | 0.04                | 3.0000         | 91.0000        | 31.5000        |
|                           | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 4             | 0               | 4                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 39            | 0               | 39                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 2-Hexanone                | 1989 | 54            | 0               | 54                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 20            | 0               | 20                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| 4-Methyl-2-pentanone      | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 190           | 8               | 181               | 1               | 0.01                | 2.0000         | 2.0000         | 2.0000         |
|                           | 1990 | 233           | 4               | 225               | 4               | 0.02                | 1.0000         | 6.0000         | 3.7500         |
|                           | 1986 | 32            | 0               | 31                | 1               | 0.03                | 2.0000         | 2.0000         | 2.0000         |
| Acetone                   | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 190           | 9               | 180               | 1               | 0.01                | 36.0000        | 36.0000        | 36.0000        |
|                           | 1990 | 233           | 1               | 232               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Benzene                   | 1986 | 32            | 14              | 5                 | 13              | 0.41                | 4.0000         | 47.0000        | 20.2308        |
|                           | 1987 | 6             | 2               | 3                 | 1               | 0.17                | 16.0000        | 16.0000        | 16.0000        |
|                           | 1988 | 56            | 10              | 34                | 12              | 0.21                | 3.0000         | 59.0000        | 14.2500        |
|                           | 1989 | 190           | 24              | 121               | 45              | 0.24                | 1.0000         | 160.0000       | 27.5111        |
| Bromodichloromethane      | 1990 | 234           | 28              | 173               | 33              | 0.14                | 1.0000         | 52.0000        | 16.0000        |
|                           | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 190           | 1               | 187               | 2               | 0.01                | 4.0000         | 5.0000         | 4.5000         |
|                           | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 233           | 0               | 231               | 2               | 0.01                | 1.0000         | 1.0000         | 1.0000         |

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TABLE 2-15 (cont.)

| Analyte              | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|----------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                      |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| Bromoform            | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 190           | 2               | 188               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1990 | 233           | 2               | 231               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Bromomethane         | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 56            | 16              | 40                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 190           | 5               | 185               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Carbon disulfide     | 1986 | 32            | 0               | 22                | 10              | 0.31                | 1.0000         | 6.0000         | 2.4000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 56            | 11              | 45                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 190           | 8               | 174               | 8               | 0.04                | 1.0000         | 7.0000         | 2.2500         |
|                      | 1990 | 233           | 2               | 231               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Carbon tetrachloride | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 43            | 0               | 42                | 1               | 0.02                | 7.0000         | 7.0000         | 7.0000         |
|                      | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 190           | 1               | 187               | 2               | 0.01                | 3.0000         | 4.0000         | 3.5000         |
|                      | 1990 | 233           | 0               | 232               | 1               | 0.00                | 2.0000         | 2.0000         | 2.0000         |
| Chlorobenzene        | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1990 | 233           | 0               | 232               | 1               | 0.00                | 2.0000         | 2.0000         | 2.0000         |
| Chloroethane         | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 56            | 22              | 34                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 190           | 4               | 186               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1990 | 233           | 1               | 232               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Chloroform           | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 43            | 0               | 42                | 1               | 0.02                | 16.0000        | 16.0000        | 16.0000        |
|                      | 1988 | 56            | 18              | 37                | 1               | 0.02                | 2.0000         | 2.0000         | 2.0000         |
|                      | 1989 | 190           | 1               | 182               | 7               | 0.04                | 1.0000         | 4.0000         | 2.0000         |
|                      | 1990 | 233           | 0               | 189               | 44              | 0.19                | 1.0000         | 29.0000        | 10.5000        |
| Chloromethane        | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 56            | 19              | 37                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 190           | 9               | 181               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |

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*Groundwater Geochemistry of Rocky Flats Plant*

**TABLE 2-15 (cont.)**

| Analyte              | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|----------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                      |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| Dibromochloromethane | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 56            | 9               | 46                | 1               | 0.02                | 3.0000         | 3.0000         | 3.0000         |
|                      | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Ethylbenzene         | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1986 | 32            | 0               | 31                | 1               | 0.03                | 1.0000         | 1.0000         | 1.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Methylene chloride   | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1986 | 32            | 2               | 9                 | 21              | 0.66                | 1.0000         | 14.0000        | 4.5238         |
|                      | 1987 | 6             | 1               | 0                 | 5               | 0.83                | 6.0000         | 45.0000        | 23.4000        |
|                      | 1988 | 56            | 12              | 16                | 28              | 0.50                | 3.0000         | 45.0000        | 13.7500        |
|                      | 1989 | 190           | 25              | 66                | 99              | 0.52                | 1.0000         | 51.0000        | 8.8889         |
| Styrene              | 1990 | 235           | 70              | 75                | 90              | 0.38                | 1.0000         | 40.0000        | 6.5778         |
|                      | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Tetrachloroethene    | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1986 | 32            | 0               | 31                | 1               | 0.03                | 1.0000         | 1.0000         | 1.0000         |
|                      | 1987 | 43            | 0               | 43                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 56            | 9               | 45                | 2               | 0.04                | 3.0000         | 37.0000        | 20.0000        |
|                      | 1989 | 190           | 0               | 185               | 5               | 0.03                | 2.0000         | 75.0000        | 23.2000        |
| Toluene              | 1990 | 233           | 0               | 230               | 3               | 0.01                | 1.0000         | 5.0000         | 2.6667         |
|                      | 1986 | 32            | 1               | 24                | 7               | 0.22                | 1.0000         | 1.0000         | 1.0000         |
|                      | 1987 | 6             | 0               | 5                 | 1               | 0.17                | 12.0000        | 12.0000        | 12.0000        |
|                      | 1988 | 56            | 20              | 35                | 1               | 0.02                | 4.0000         | 4.0000         | 4.0000         |
|                      | 1989 | 190           | 2               | 183               | 5               | 0.03                | 1.0000         | 5.0000         | 3.0000         |
| Total xylenes        | 1990 | 233           | 1               | 217               | 15              | 0.06                | 1.0000         | 2.0000         | 1.3333         |
|                      | 1986 | 32            | 0               | 31                | 1               | 0.03                | 4.0000         | 4.0000         | 4.0000         |
|                      | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Trichloroethene      | 1990 | 232           | 1               | 231               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                      | 1986 | 32            | 0               | 16                | 16              | 0.50                | 1.0000         | 5.0000         | 2.0625         |
|                      | 1987 | 43            | 0               | 42                | 1               | 0.02                | 209.0000       | 209.0000       | 209.0000       |
|                      | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |

TABLE 2-15 (cont.)

| Analyte                   | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|---------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                           |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| Vinyl acetate             | 1989 | 190           | 0               | 181               | 9               | 0.05                | 1.0000         | 13.0000        | 4.0000         |
|                           | 1990 | 233           | 0               | 228               | 5               | 0.02                | 1.0000         | 5.0000         | 2.8000         |
|                           | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| Vinyl chloride            | 1989 | 190           | 20              | 170               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 231           | 0               | 231               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| cis-1,3-Dichloropropene   | 1989 | 190           | 5               | 185               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 233           | 0               | 232               | 1               | 0.00                | 2.0000         | 2.0000         | 2.0000         |
|                           | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| trans-1,2-Dichloroethene  | 1989 | 190           | 0               | 190               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 4             | 0               | 4                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 49            | 0               | 49                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
| trans-1,3-Dichloropropene | 1990 | 2             | 0               | 2                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1986 | 32            | 0               | 32                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1987 | 6             | 0               | 6                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1988 | 56            | 9               | 47                | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1989 | 190           | 2               | 188               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |
|                           | 1990 | 233           | 0               | 233               | 0               | 0.00                | 0.0000         | 0.0000         | 0.0000         |

TABLE 2-16 SUMMARY OF EQUIPMENT-RINSATE-BLANK RESULTS FOR VOLATILE ORGANIC COMPOUNDS BY YEAR

| Analyte                   | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|---------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                           |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| 1,1,1,2-Tetrachloroethane | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,1,1-Trichloroethane     | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 2               | 36                | 1               | 0.03                | 2.0000         | 2.0000         | 2.000          |
|                           | 1992 | 66            | 0               | 63                | 3               | 0.05                | 0.1200         | 2.0000         | 0.940          |
| 1,1,2,2-Tetrachloroethane | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,1,2-Trichloroethane     | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,1-Dichloroethane        | 1990 | 26            | 1               | 25                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,1-Dichloroethene        | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 65                | 1               | 0.02                | 3.0000         | 3.0000         | 3.000          |
| 1,1-Dichloropropane       | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,2,3-Trichlorobenzene    | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,2,4-Trichlorobenzene    | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,2-Dibromoethane         | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,2-Dichlorobenzene       | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,2-Dichloroethane        | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,2-Dichloroethene        | 1990 | 25            | 0               | 25                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 35            | 2               | 33                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 52            | 0               | 52                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,2-Dichloropropane       | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,2-Dimethylbenzene       | 1990 | 2             | 0               | 2                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 13            | 0               | 13                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,3-Dichlorobenzene       | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,3-Dichloropropane       | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 1,3-Dimethylbenzene       | 1992 | 13            | 0               | 11                | 2               | 0.15                | 0.3000         | 0.3800         | 0.340          |
| 1,4-Dichlorobenzene       | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |



*Groundwater Geochemistry of Rocky Flats Plant*

**TABLE 2-16 (cont.)**

| Analyte                   | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|---------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                           |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| 2-Butanone                | 1990 | 26            | 5               | 21                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 15              | 24                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 52            | 15              | 37                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 2-Chloroethyl vinyl ether | 1990 | 2             | 0               | 2                 | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 2-Hexanone                | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 4               | 35                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 52            | 6               | 46                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| 4-Methyl-2-pentanone      | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 2               | 37                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 52            | 0               | 52                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Acetone                   | 1990 | 26            | 3               | 11                | 12              | 0.46                | 5.0000         | 25.0000        | 10.750         |
|                           | 1991 | 39            | 4               | 31                | 4               | 0.10                | 2.0000         | 15.0000        | 8.250          |
|                           | 1992 | 52            | 1               | 41                | 10              | 0.19                | 1.0000         | 13.0000        | 4.400          |
| Benzene                   | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 62                | 4               | 0.06                | 0.2000         | 0.7000         | 0.400          |
| Benzene, 1,2,4-trimethyl  | 1992 | 14            | 0               | 13                | 1               | 0.07                | 0.1000         | 0.1000         | 0.100          |
| Benzene, 1,3,5-trimethyl  | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Bromobenzene              | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Bromochloromethane        | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Bromodichloromethane      | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 2               | 37                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Bromoform                 | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 2               | 37                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Bromomethane              | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 5               | 34                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Carbon disulfide          | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 2               | 37                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 52            | 0               | 52                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Carbon tetrachloride      | 1990 | 26            | 0               | 25                | 1               | 0.04                | 1.0000         | 1.0000         | 1.000          |
|                           | 1991 | 39            | 2               | 37                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 64                | 2               | 0.03                | 0.6000         | 5.3000         | 2.950          |
| Chlorobenzene             | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                           | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Chloroethane              | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |

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TABLE 2-16 (cont.)

| Analyte                       | Year | Total Samples | Number Rejected | Number Undetected | Number Detected | Detection Frequency | Concentration  |                |                |
|-------------------------------|------|---------------|-----------------|-------------------|-----------------|---------------------|----------------|----------------|----------------|
|                               |      |               |                 |                   |                 |                     | Minimum (µg/L) | Maximum (µg/L) | Average (µg/L) |
| Chloroform                    | 1991 | 39            | 3               | 36                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1990 | 26            | 0               | 25                | 1               | 0.04                | 1.0000         | 1.0000         | 1.000          |
|                               | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1992 | 66            | 0               | 65                | 1               | 0.02                | 0.1000         | 0.1000         | 0.100          |
| Chloromethane                 | 1990 | 26            | 1               | 24                | 1               | 0.04                | 5.0000         | 5.0000         | 5.000          |
|                               | 1991 | 39            | 1               | 36                | 2               | 0.05                | 2.0000         | 7.0000         | 4.500          |
|                               | 1992 | 66            | 1               | 59                | 6               | 0.09                | 0.7000         | 12.0000        | 3.716          |
| Cumene                        | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Dibromochloromethane          | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Dibromomethane                | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Dichlorodifluoromethane       | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Ethylbenzene                  | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Hexachlorobutadiene           | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Methylene chloride            | 1990 | 27            | 10              | 11                | 6               | 0.22                | 2.0000         | 8.0000         | 5.166          |
|                               | 1991 | 39            | 2               | 33                | 4               | 0.10                | 1.0000         | 5.0000         | 3.250          |
|                               | 1992 | 66            | 1               | 53                | 12              | 0.18                | 0.7000         | 15.0000        | 3.600          |
| Naphthalene                   | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Propane, 1,2-dibromo-3-chloro | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Styrene                       | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1991 | 39            | 2               | 37                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1992 | 66            | 0               | 66                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
| Tetrachloroethene             | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1992 | 66            | 0               | 60                | 6               | 0.09                | 0.1400         | 3.3000         | 1.790          |
| Toluene                       | 1990 | 26            | 1               | 24                | 1               | 0.04                | 1.0000         | 1.0000         | 1.000          |
|                               | 1991 | 39            | 1               | 33                | 5               | 0.13                | 1.0000         | 110.0000       | 30.400         |
|                               | 1992 | 66            | 1               | 31                | 34              | 0.52                | 0.1400         | 340.0000       | 16.754         |
| Total xylenes                 | 1990 | 26            | 0               | 26                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1992 | 53            | 0               | 51                | 2               | 0.04                | 0.3000         | 1.0000         | 0.650          |
| Trichloroethene               | 1990 | 26            | 0               | 25                | 1               | 0.04                | 2.0000         | 2.0000         | 2.000          |
|                               | 1991 | 39            | 1               | 38                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |
|                               | 1992 | 66            | 0               | 58                | 8               | 0.12                | 0.1200         | 4.0000         | 1.272          |
| Trichlorofluoromethane        | 1992 | 14            | 0               | 14                | 0               | 0.00                | 0.0000         | 0.0000         | 0.000          |

*Groundwater Geochemistry of Rocky Flats Plant*

**TABLE 2-16 (cont.)**

| Analyte                   | Year | Total<br>Samples | Number<br>Rejected | Number<br>Undetected | Number<br>Detected | Detection<br>Frequency | Concentration                  |                                |                                |
|---------------------------|------|------------------|--------------------|----------------------|--------------------|------------------------|--------------------------------|--------------------------------|--------------------------------|
|                           |      |                  |                    |                      |                    |                        | Minimum<br>( $\mu\text{g/L}$ ) | Maximum<br>( $\mu\text{g/L}$ ) | Average<br>( $\mu\text{g/L}$ ) |
| Vinyl acetate             | 1990 | 26               | 0                  | 26                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
|                           | 1991 | 39               | 5                  | 34                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
|                           | 1992 | 41               | 6                  | 35                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| Vinyl chloride            | 1990 | 26               | 0                  | 26                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
|                           | 1991 | 39               | 1                  | 38                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
|                           | 1992 | 66               | 0                  | 65                   | 1                  | 0.02                   | 0.1200                         | 0.1200                         | 0.120                          |
| cis-1,2-Dichloroethene    | 1992 | 14               | 0                  | 14                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| cis-1,3-Dichloropropene   | 1990 | 26               | 0                  | 26                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
|                           | 1991 | 39               | 1                  | 38                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
|                           | 1992 | 65               | 0                  | 65                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| n-Butylbenzene            | 1992 | 14               | 0                  | 14                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| n-Propylbenzene           | 1992 | 14               | 0                  | 14                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| o-Chlorotoluene           | 1992 | 14               | 0                  | 14                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| p-Chlorotoluene           | 1992 | 14               | 0                  | 14                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| p-Cymene                  | 1992 | 14               | 0                  | 14                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| p-Xylene                  | 1992 | 3                | 0                  | 3                    | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| sec-Butylbenzene          | 1992 | 14               | 0                  | 13                   | 1                  | 0.07                   | 0.8000                         | 0.8000                         | 0.800                          |
| sec-Dichloropropane       | 1992 | 14               | 0                  | 14                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| tert-Butylbenzene         | 1992 | 14               | 0                  | 14                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| trans-1,2-Dichloroethene  | 1990 | 1                | 0                  | 1                    | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
|                           | 1991 | 4                | 0                  | 4                    | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
|                           | 1992 | 14               | 0                  | 14                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
| trans-1,3-Dichloropropene | 1990 | 26               | 0                  | 26                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
|                           | 1991 | 39               | 1                  | 38                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |
|                           | 1992 | 65               | 0                  | 65                   | 0                  | 0.00                   | 0.0000                         | 0.0000                         | 0.000                          |

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TABLE 2-17 RELATIVE PERCENT DIFFERENCE FOR VOLATILE ORGANIC COMPOUNDS IN FIELD DUPLICATES

| Analyte                   | Number of Duplicate Samples | Relevant Percent Difference |         |         |
|---------------------------|-----------------------------|-----------------------------|---------|---------|
|                           |                             | Minimum                     | Maximum | Average |
| 1,1,1,2-Tetrachloroethane | 2                           | 0                           | 185     | 92      |
| 1,1,1-Trichloroethane     | 14                          | 0                           | 192     | 54      |
| 1,1,2,2-Tetrachloroethane | 2                           | 0                           | 185     | 92      |
| 1,1,2-Trichloroethane     | 4                           | 0                           | 200     | 98      |
| 1,1-Dichloroethane        | 16                          | 0                           | 199     | 62      |
| 1,1-Dichloroethene        | 13                          | 0                           | 188     | 70      |
| 1,1-Dichloropropene       | 2                           | 0                           | 185     | 92      |
| 1,2,3-Trichlorobenzene    | 2                           | 0                           | 185     | 92      |
| 1,2,3-Trichloropropane    | 2                           | 0                           | 185     | 92      |
| 1,2,4-Trichlorobenzene    | 2                           | 0                           | 185     | 92      |
| 1,2-Dibromoethane         | 2                           | 0                           | 185     | 92      |
| 1,2-Dichlorobenzene       | 2                           | 0                           | 185     | 92      |
| 1,2-Dichloroethane        | 2                           | 0                           | 185     | 92      |
| 1,2-Dichloroethene        | 16                          | 0                           | 59      | 12      |
| 1,2-Dichloropropane       | 3                           | 0                           | 185     | 62      |
| 1,2-Dimethylbenzene       | 2                           | 0                           | 185     | 92      |
| 1,3-Dichlorobenzene       | 2                           | 0                           | 185     | 92      |
| 1,3-Dichloropropane       | 2                           | 0                           | 185     | 92      |
| 1,3-Dimethylbenzene       | 2                           | 0                           | 185     | 92      |
| 1,4-Dichlorobenzene       | 2                           | 0                           | 185     | 92      |
| 2-Butanone                | 3                           | 11                          | 67      | 42      |
| Acetone                   | 20                          | 0                           | 173     | 54      |
| Benzene                   | 11                          | 0                           | 185     | 34      |
| Benzene, 1,2,4-trimethyl- | 2                           | 0                           | 185     | 92      |
| Benzene, 1,3,5-trimethyl- | 2                           | 0                           | 185     | 92      |
| Bromobenzene              | 2                           | 0                           | 185     | 92      |
| Bromochloromethane        | 2                           | 0                           | 185     | 92      |
| Bromodichloromethane      | 5                           | 0                           | 200     | 118     |
| Bromoform                 | 2                           | 0                           | 185     | 92      |
| Bromomethane              | 2                           | 0                           | 185     | 92      |
| Carbon disulfide          | 7                           | 0                           | 67      | 24      |
| Carbon tetrachloride      | 23                          | 4                           | 171     | 64      |
| Chlorobenzene             | 2                           | 0                           | 185     | 92      |
| Chloroethane              | 4                           | 0                           | 185     | 46      |
| Chloroform                | 23                          | 0                           | 148     | 38      |
| Chloromethane             | 2                           | 0                           | 185     | 92      |
| Cumene                    | 2                           | 0                           | 185     | 92      |

TABLE 2-17 (cont.)

| Analyte                        | Number of Duplicate Samples | Relevant Percent Difference |         |         |
|--------------------------------|-----------------------------|-----------------------------|---------|---------|
|                                |                             | Minimum                     | Maximum | Average |
| Dibromochloromethane           | 2                           | 0                           | 185     | 92      |
| Dibromomethane                 | 2                           | 0                           | 185     | 92      |
| Dichlorodifluoromethane        | 2                           | 0                           | 185     | 92      |
| Ethylbenzene                   | 2                           | 0                           | 185     | 92      |
| Hexachlorobutadiene            | 2                           | 0                           | 185     | 92      |
| Methylene chloride             | 49                          | 0                           | 199     | 51      |
| Naphthalene                    | 2                           | 0                           | 185     | 92      |
| Propane, 1,2-dibromo-3-chloro- | 6                           | 0                           | 185     | 113     |
| Styrene                        | 3                           | 0                           | 185     | 84      |
| Tetrachloroethene              | 35                          | 0                           | 190     | 42      |
| Toluene                        | 4                           | 0                           | 185     | 82      |
| Total xylenes                  | 1                           | 67                          | 67      | 67      |
| Trichloroethene                | 36                          | 0                           | 147     | 29      |
| Trichlorofluoromethane         | 2                           | 0                           | 185     | 92      |
| Vinyl chloride                 | 7                           | 0                           | 185     | 28      |
| cis-1,2-Dichloroethene         | 10                          | 3                           | 113     | 42      |
| cis-1,3-Dichloropropene        | 2                           | 0                           | 185     | 92      |
| n-Butylbenzene                 | 2                           | 0                           | 185     | 92      |
| n-Propylbenzene                | 2                           | 0                           | 185     | 92      |
| o-Chlorotoluene                | 2                           | 0                           | 185     | 92      |
| p-Chlorotoluene                | 2                           | 0                           | 185     | 92      |
| p-Cymene                       | 2                           | 0                           | 185     | 92      |
| sec-Butylbenzene               | 3                           | 0                           | 185     | 68      |
| sec-Dichloropropane            | 2                           | 0                           | 185     | 92      |
| tert-Butylbenzene              | 2                           | 0                           | 185     | 92      |
| trans-1,2-Dichloroethene       | 10                          | 0                           | 199     | 84      |
| trans-1,3-Dichloropropene      | 2                           | 0                           | 185     | 92      |

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**TABLE 2-18 SUMMARY OF FIELD, TRAVEL, AND EQUIPMENT-RINSATE-BLANK RESULTS FOR FIELD MEASUREMENTS**

| Analyte                            | Year | Total Samples | Minimum  | Maximum  | Average  |
|------------------------------------|------|---------------|----------|----------|----------|
| <b>FIELD BLANK</b>                 |      |               |          |          |          |
| Alkalinity (mg/L)                  | 1986 | 33            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1987 | 33            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1988 | 57            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1989 | 115           | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1990 | 14            | 0.0000   | 0.0000   | 0.0000   |
| Dissolved oxygen (mg/L)            | 1990 | 1             | 0.9000   | 0.9000   | 0.9000   |
| Silica (mg/L)                      | 1986 | 33            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1987 | 33            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1988 | 57            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1989 | 115           | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1990 | 14            | 0.0000   | 0.0000   | 0.0000   |
| Specific conductance ( $\mu$ S/cm) | 1989 | 1             | 3120.000 | 3120.000 | 3120.000 |
|                                    | 1990 | 1             | 770.0000 | 770.0000 | 770.0000 |
| pH                                 | 1989 | 1             | 7.4000   | 7.4000   | 7.4000   |
|                                    | 1990 | 1             | 7.9600   | 7.9600   | 7.9600   |
| <b>TRIP BLANK</b>                  |      |               |          |          |          |
| Alkalinity (mg/L)                  | 1986 | 33            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1987 | 46            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1988 | 57            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1989 | 227           | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1990 | 134           | 0.0000   | 0.0000   | 0.0000   |
| Silica (mg/L)                      | 1986 | 33            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1987 | 46            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1988 | 57            | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1989 | 227           | 0.0000   | 0.0000   | 0.0000   |
|                                    | 1990 | 134           | 0.0000   | 0.0000   | 0.0000   |
| <b>RINSATE BLANK</b>               |      |               |          |          |          |
| Dissolved oxygen (mg/L)            | 1992 | 1             | 7.3000   | 7.3000   | 7.3000   |
| Specific conductance ( $\mu$ S/cm) | 1992 | 1             | 370.0000 | 370.0000 | 370.0000 |
| pH                                 | 1992 | 1             | 7.4200   | 7.4200   | 7.4200   |

**TABLE 2-19 SUMMARY OF RELATIVE PERCENT DIFFERENCE  
FOR DUPLICATES OF FIELD MEASUREMENTS**

| Analyte              | Number of<br>Duplicate<br>Samples | Relevant Percent Difference |         |         |
|----------------------|-----------------------------------|-----------------------------|---------|---------|
|                      |                                   | Minimum                     | Maximum | Average |
| Alkalinity           | 122                               | 0                           | 200     | 8       |
| Dissolved oxygen     | 15                                | 0                           | 60      | 4       |
| Silica               | 122                               | 0                           | 200     | 8       |
| Specific conductance | 70                                | 0                           | 22      | 2       |
| pH                   | 71                                | 0                           | 12      | 1       |

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**APPENDIX A**  
**ARCHIVED QUALITY CONTROL SAMPLE DATA**

## **APPENDIX A**

The attached floppy diskette contains the following archived data files:

- **METAPEND.ARC** - an archive containing an ASCII file of all blank samples in which metals were detected (METQ.TXT), an ASCII file of all field duplicate samples which could not be matched with real samples (MTNOFIND.TXT), and a file containing a list of all records that were ignored during the QA/QC review (METERR.TXT).
- **RDAPEND.ARC** - an archive for radionuclide analytes containing an ASCII file of all blank samples that were not rejected (RADQ.TXT) and an ASCII file of all field duplicate samples which could not be matched with real samples (RDNOFIND.TXT).
- **FLDAPEND.ARC** - an archive for field measurements containing an ASCII file of all blank samples that were not rejected (FLDQ.TXT) and an ASCII file of all field duplicate samples which could not be matched with real samples (FDNOFIND.TXT).
- **VOAPEND.ARC** - an archive for volatile organic compounds containing a file of all blank samples in which volatile organic compounds were detected (VOAQ.TXT) and an ASCII file of all field duplicate samples which could not be matched with real samples (VONOFIND.TXT).
- **SEMAPEND.ARC** - an archive for semivolatile organic compounds containing a file of all blank samples in which organic compounds were detected (SEMIQ.TXT) and an ASCII file of all field duplicate samples which could not be matched with real samples (SVNOFIND.TXT).
- **CONAPEND.ARC** - an archive for conventional measurements containing a file of all blank samples for which measurements were detected (CONQ.TXT) and an ASCII file of all field duplicate samples which could not be matched with real samples (CONOFIND.TXT).

**APPENDIX B**  
**LIST OF GROUNDWATER ANALYTES**

## **APPENDIX B**

### **Dissolved Metals**

Aluminum  
Antimony  
Arsenic  
Barium  
Beryllium  
Cadmium  
Calcium  
Cesium  
Chromium  
Cobalt  
Copper  
Cyanide  
Iron  
Lead  
Lithium  
Magnesium  
Manganese  
Mercury  
Molybdenum  
Nickel  
Phosphorus  
Potassium  
Selenium  
Silicon  
Silver  
Sodium  
Strontium  
Thallium  
Tin  
Vanadium  
Zinc

### **Total Metals**

Aluminum  
Antimony  
Arsenic  
Barium

Beryllium  
Cadmium  
Calcium  
Cesium  
Chromium  
Cobalt  
Copper  
Cyanide  
Iron  
Lead  
Lithium  
Magnesium  
Manganese  
Mercury  
Molybdenum  
Nickel  
Phosphorus  
Potassium  
Selenium  
Silica, Dissolved  
Silicon  
Silver  
Sodium  
Strontium  
Thallium  
Tin  
Vanadium  
Zinc

### **Dissolved Radionuclides**

Americium-241  
Cesium-137  
Gross Alpha, Dissolved  
Gross Alpha - Suspended  
Gross Alpha Particle Radioactivity  
Gross Beta - Dissolved  
Gross Beta - Suspended  
Gross Beta Particle Radioactivity  
Plutonium-239

Plutonium-239/240  
Radium-226  
Radium-228  
Strontium-89  
Strontium-89,90  
Strontium-90  
Total Radiocesium  
Tritium  
Uranium-233,-234  
Uranium-235  
Uranium-235/236  
Uranium-238

**Total Radionuclides**

Americium-241  
Cesium  
Cesium-137  
Gross Alpha - Dissolved  
Gross Alpha - Suspended  
Gross Alpha Particle Radioactivity  
Gross Beta - Dissolved  
Gross Beta - Suspended  
Gross Beta Particle Radioactivity  
Plutonium-238  
Plutonium-239  
Plutonium-239/240  
Radium-226  
Strontium-89  
Strontium-89,90  
Strontium-90  
Total Radiocesium  
Tritium  
Uranium-233,-234  
Uranium-235  
Uranium-235/236  
Uranium-238

**Field Measurements**

Alkalinity, Field Measured  
Dissolved Oxygen

Silica, Field Measured  
Specific Conductance  
pH, Field Measured

**Water Quality Parameters**

Alkalinity as  $\text{CaCO}_3$   
Ammonia  
Bicarbonate  
Bicarbonate as  $\text{CaCO}_3$   
Carbonate  
Carbonate as  $\text{CaCO}_3$   
Chemical Oxygen Demand  
Chloride  
Cyanide  
Cyanides  
Fluoride  
Fluoride, Soluble  
Hexavalent Chromium  
Hydrocyanic Acid  
Nitrate  
Nitrate/Nitrite  
Nitrite  
Oil and Grease  
Orthophosphate  
Phosphate  
Phosphorus  
Silica, Dissolved  
Silicon  
Sodium Fluoride  
Sodium Sulfate  
Solids, Nonvolatile Suspended  
Sulfate  
Total Dissolved Solids  
Total Organic Carbon  
Total Solids  
Total Suspended Solids  
pH



**Pesticides**

4,4'-DDD  
4,4'-DDE  
4,4'-DDT  
Aldrin  
Chlordane  
Dieldrin  
Endosulfan I  
Endosulfan II  
Endosulfan Sulfate  
Endrin  
Endrin Ketone  
Heptachlor  
Heptachlor Epoxide  
Methoxychlor  
Parathion, Ethyl  
Toxaphene  
alpha-BHC  
alpha-Chlordane  
beta-BHC  
delta-BHC  
gamma-BHC (Lindane)  
gamma-Chlordane

**PCBs**

Aroclor-1016  
Aroclor-1221  
Aroclor-1232  
Aroclor-1242  
Aroclor-1248  
Aroclor-1254  
Aroclor-1260

**ABN Compounds**

1,2,4-Trichlorobenzene  
1,2-Dichlorobenzene  
1,3-Dichlorobenzene  
1,4-Dichlorobenzene  
2,4,5-Trichlorophenol

2,4,6-Trichlorophenol  
2,4-Dichlorophenol  
2,4-Dimethylphenol  
2,4-Dinitrophenol  
2,4-Dinitrotoluene  
2,6-Dinitrotoluene  
2-Chloronaphthalene  
2-Chlorophenol  
2-Methylnaphthalene  
2-Methylphenol  
2-Nitroaniline  
2-Nitrophenol  
3,3'-Dichlorobenzidine  
3-Nitroaniline  
4,6-Dinitro-2-methylphenol  
4-Bromophenyl Phenyl Ether  
4-Chloro-3-methylphenol  
4-Chloroaniline  
4-Chlorophenyl Phenyl Ether  
4-Methylphenol  
4-Nitroaniline  
4-Nitrophenol  
Acenaphthene  
Acenaphthylene  
Anthracene  
Benzo(a)anthracene  
Benzo(a)pyrene  
Benzo(b)fluoranthene  
Benzo(ghi)perylene  
Benzo(k)fluoranthene  
Benzoic Acid  
Benzyl Alcohol  
Bis(2-chloroethoxy)methane  
Bis(2-chloroethyl)ether  
Bis(2-chloroisopropyl)ether  
Bis(2-Ethylhexyl)phthalate  
Butyl Benzyl Phthalate  
Chrysene  
Di-n-butyl Phthalate  
Di-n-octyl Phthalate  
Dibenzo(a,h)anthracene  
Dibenzofuran  
Diethyl Phthalate  
Dimethyl Phthalate

Fluoroanthene  
Fluorene  
Hexachlorobenzene  
Hexachlorobutadiene  
Hexachlorocyclopentadiene  
Hexachloroethane  
Indeno(1,2,3-cd)pyrene  
Isophorone  
N-nitroso-di-n-propylamine  
N-nitrosodiphenylamine  
Naphthalene  
Nitrobenzene  
Pentachlorophenol  
Phenanthrene  
Phenol  
Pyrene

**Volatile Organic Compounds (VOCs)**

1,1,1,2-Tetrachloroethane  
1,1,1-Trichloroethane  
1,1,2,2-Tetrachloroethane  
1,1,2-Trichloroethane  
1,1-Dichloroethane  
1,1-Dichloroethene  
1,1-Dichloropropene  
1,2,3-Trichlorobenzene  
1,2,3-Trichloropropane  
1,2,4-Trichlorobenzene  
1,2-Dibromoethane  
1,2-Dichlorobenzene  
1,2-Dichloroethane  
1,2-Dichloroethene  
1,2-Dichloropropane  
1,2-Dimethylbenzene  
1,3-Dichlorobenzene  
1,3-Dichloropropane  
1,3-Dimethylbenzene  
1,4-Dichlorobenzene  
2-Butanone  
2-Chloroethyl Vinyl Ether  
2-Hexanone  
4-Methyl-2-pentanone  
Acetone

Benzene  
Benzene, 1,2,4-Trimethyl-  
Benzene, 1,3,5-Trimethyl-  
Bromobenzene  
Bromochloromethane  
Bromodichloromethane  
Bromoform  
Bromomethane  
Carbon Disulfide  
Carbon Tetrachloride  
Chlorobenzene  
Chloroethane  
Chloroform  
Chloromethane  
Cumene  
Dibromochloromethane  
Dibromomethane  
Dichlorodifluoromethane  
Ethylbenzene  
Hexachlorobutadiene  
Methylene Chloride  
Naphthalene  
Propane, 1,2-Dibromo-3-chloro-  
Styrene  
Tetrachloroethene  
Toluene  
Total Xylenes  
Trichloroethene  
Trichlorofluoromethane  
Vinyl Acetate  
Vinyl Chloride  
cis-1,2-Dichloroethene  
cis-1,3-Dichloropropene  
n-Butylbenzene  
n-Propylbenzene  
o-Chlorotoluene  
p-Chlorotoluene  
p-Cymene  
p-Xylene  
sec-Butylbenzene  
sec-Dichloropropane  
tert-Butylbenzene  
trans-1,2-Dichloroethene  
trans-1,3-Dichloropropene

**APPENDIX C**  
**LABORATORY DATA QUALIFIERS**

## APPENDIX C

## Laboratory Data Qualifiers

| Qualifier | Definition   | Include in Data Analysis      | Detected ("Hit") |
|-----------|--|-------------------------------|------------------|
| +         | inorganics: correlation coefficient for the matrix spike analysis is less than 0.995 (estimated value)   | yes                           | yes              |
| -         | inorganics: duplicate analysis is not within control limits (estimated value)  | yes                           | yes              |
| A         | organics: identifies tentatively identified compound (TIC) as a suspected aldol condensation product   | yes<br>remove to<br>TIC table | no               |
| B         | organics: warns that analyte also detected in blank<br><i>note: for common lab contaminants include as hit if blank result &gt; 10 x det. limit; for all other organics include as hit if blank result &gt; 5 x det. limit</i> | yes                           | yes              |
|           | inorganics: reported value is less than CRDL but greater than IDL  | yes                           | yes              |
|           | rads: constituent also detected in associated blank whose concentration was greater than CRDL and/or minimum detectable activity (estimated value)   | yes                           | yes              |
| C         | organics: pesticide result confirmed by GC/MS  | yes                           | yes              |
|           | rads: presence of high TDS in sample increased minimum detectable activity   | yes                           | yes              |
| D         | organics: identified in an analysis at a secondary dilution  | yes                           | yes              |
| E         | organics: compound exceeded calibration range of instrument, sample must be reanalyzed   | no                            | no               |
|           | inorganics: value is an estimate due to interference (estimated value)   | yes                           | yes              |
| F         | rads: for alpha spectrometry - FWHM exceeded acceptable limits (estimated)   | yes                           | yes              |
| G         | TOC: dilution result exceeded range of instrument, estimated result  | yes                           | yes              |
| H         | rads: sample analysis performed outside of method-specified maximum hold-  | yes                           | yes              |
| I         | organics: interference with target peak (estimated value)  | yes                           | yes              |
| JB        | organics: result below detection limit and analyte detected in lab blank   | yes                           | no               |
| J         | organics: MS data indicate presence of compound but below detection limit (estimated value)  | yes                           | yes              |
|           | inorganics: value greater than IDL but control sample analysis not within control limits (estimated value)   | yes                           | yes              |
| L         | undefined  | no                            | no               |

| Qualifier | Definition   | Include in Data Analysis  | Detected ("Hit")         |
|-----------|--|---|--------------------------|
| N         | organics: compound presumed present (TIC)<br><br>inorganics: spiked sample recovery is not within control limits (estimated value)   | yes<br>remove to TIC table<br>yes                               | no<br><br>yes            |
| N*        | inorganics: spiked sample recovery and duplicate analysis are not within control limits (estimated value)  | yes   | yes                      |
| R         | validation code for rejected data entered in lab qualifier field/unusable data   | no  | no                       |
| S         | inorganics: the reported value determined by the method of standard  | yes   | yes                      |
| U         | organics and inorganics: analyte analyzed but not detected at the quantitation   | yes   | no                       |
| UC        | organics: pesticide result confirmed but below detection limit   | yes   | no                       |
| UE        | rads: detection limit reported as result (?)   | no  | no                       |
| UJ        | organics: analyzed but not above the detection limit, estimated value  | yes   | no                       |
| UN        | organics: compound presumed present but below detection limit<br><br>inorganics: spiked sample recovery not within control limits and sample result below detection limit  | yes (TICs)<br><br>yes   | no<br><br>no             |
| UW        | inorganics: post-digestion spike for GFAA analysis is out of control limits and sample result is below detection limit   | yes   | no                       |
| UX        |  | yes   | no                       |
| V         | validation code for valid data entered into lab qualifier field  | yes   | yes                      |
| W         | inorganics: post-digestion spike for GFAA analysis is out of control limits while sample absorbance < 50% of spike absorbance  | yes   | yes                      |
| X         | organics (pre-1992): lab software flag (combines more than one qualifier) - not defined<br><br>inorganics (pre-1992): detection limit greater than normal, sample matrix interference<br><br>other (OU7 RFI/RI samples): result by calculation defined in GRRASP | no (unless accompanied by a validated result)<br>yes<br><br>yes | no<br><br>yes<br><br>yes |
| Y         | rads: chemical yield exceeded acceptable limits (estimated value)  | yes   | yes                      |

Note on use of X qualifiers: X is defined in the GRRASP as a result determined by calculation not by direct laboratory analysis. Therefore, for samples analyzed during the period that GRRASP has been in effect (since January 1992) the results qualified by an X will be treated as estimated values (similar to J). For historic data, when GRRASP was not used by laboratories, an X qualifier has two definitions. For organics, the X is a flag entered manually by the laboratory, but is not defined in RFEDS. Therefore, organic results qualified by X are not considered usable data, unless a validated result is given. For inorganics, an X qualifier indicates that the detection limit for the analyte is higher than normal due to matrix interference.

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An inorganic qualified with an X will be treated like a J result. The X qualifier is sometimes also used with other qualifiers (i.e., UX, XJ). In these cases the meaning of X depends on the analyte and the date of the analysis.

### Validation Qualifiers

| Qualifier | Definition                              | Include in Data Analysis |
|-----------|---|--------------------------|
| J         | estimated result                        | yes                      |
| B         | lab qualifier                           | no                       |
| C         | lab qualifier                           | no                       |
| N         | lab qualifier                           | no                       |
| S         | lab qualifier                           | no                       |
| P         | undefined                               | no                       |
| A         | acceptable result                       | yes                      |
| JA        | acceptable result (for estimated value) | yes                      |
| R         | rejected result                         | no                       |
| V         | valid result                            | yes                      |

**APPENDIX D**  
**CHEMICAL CONSTITUENTS OF GROUNDWATER**

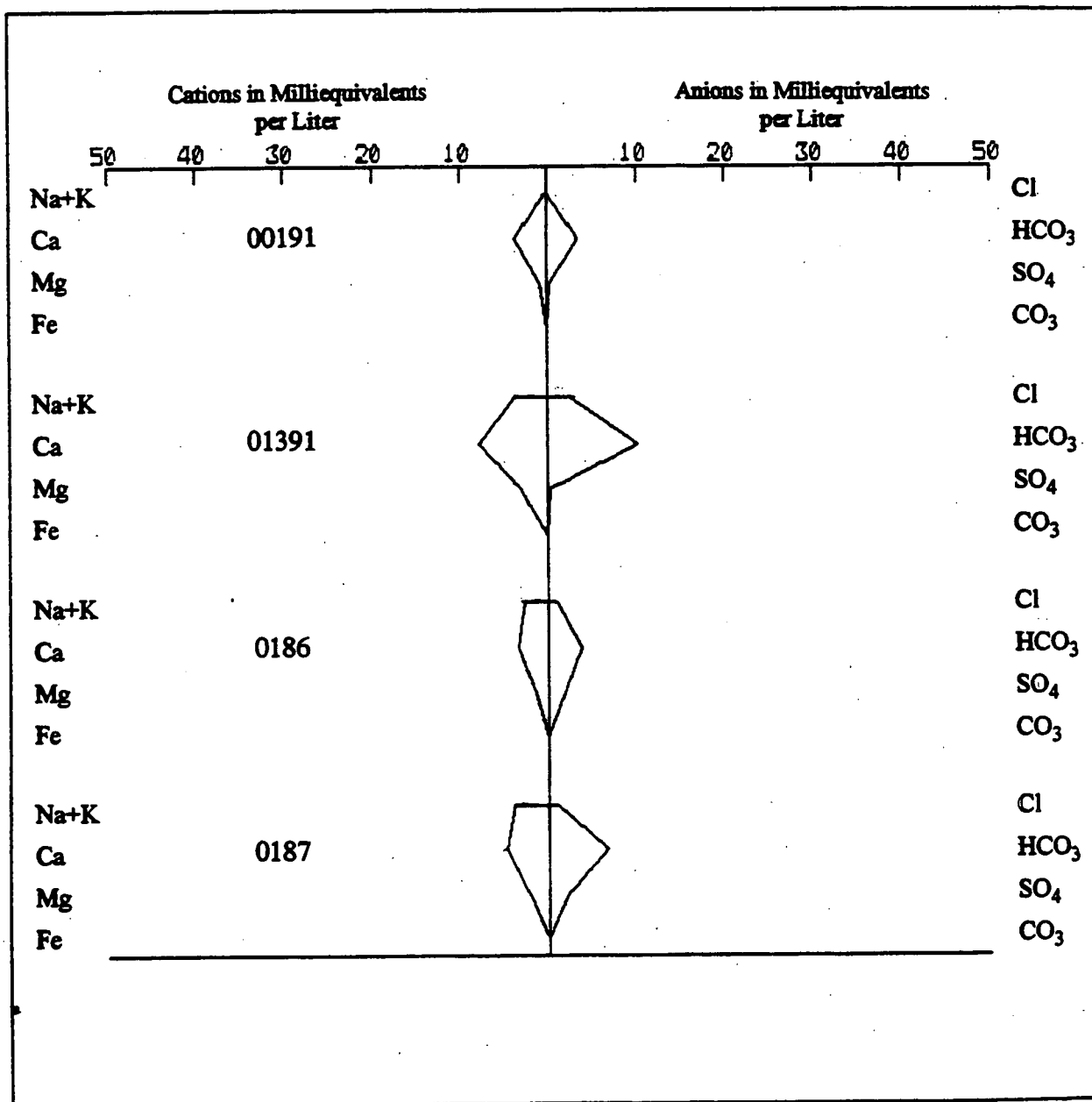
## **APPENDIX D**

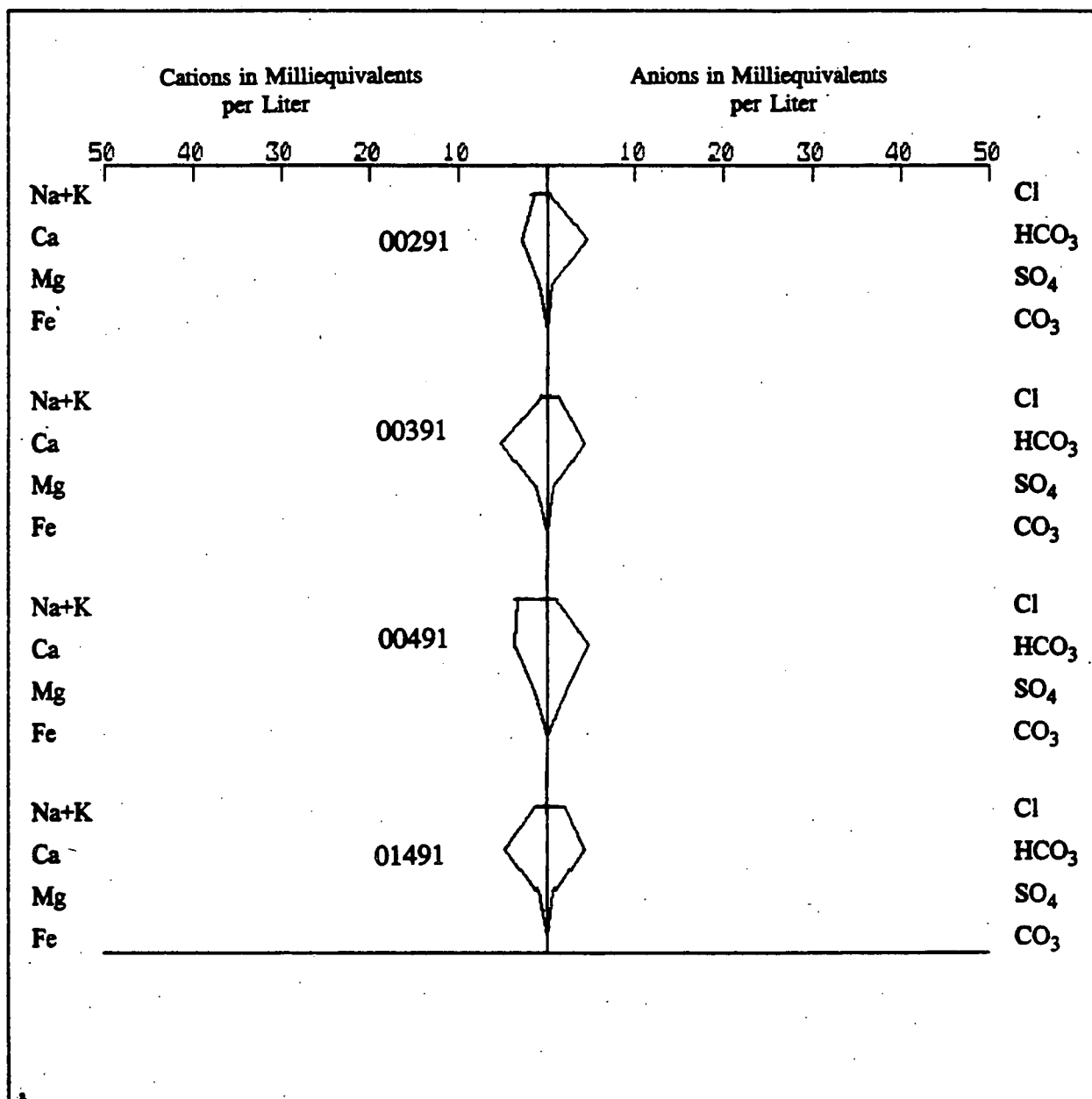
The Stiff plots contained in this appendix depict the major-ion chemistry of groundwater, as measured in samples obtained from groundwater wells from across the RFP. Each plot is representative of the major-ion chemistry of groundwater at each sampling site. Two hundred eighty-seven wells are represented in this appendix.

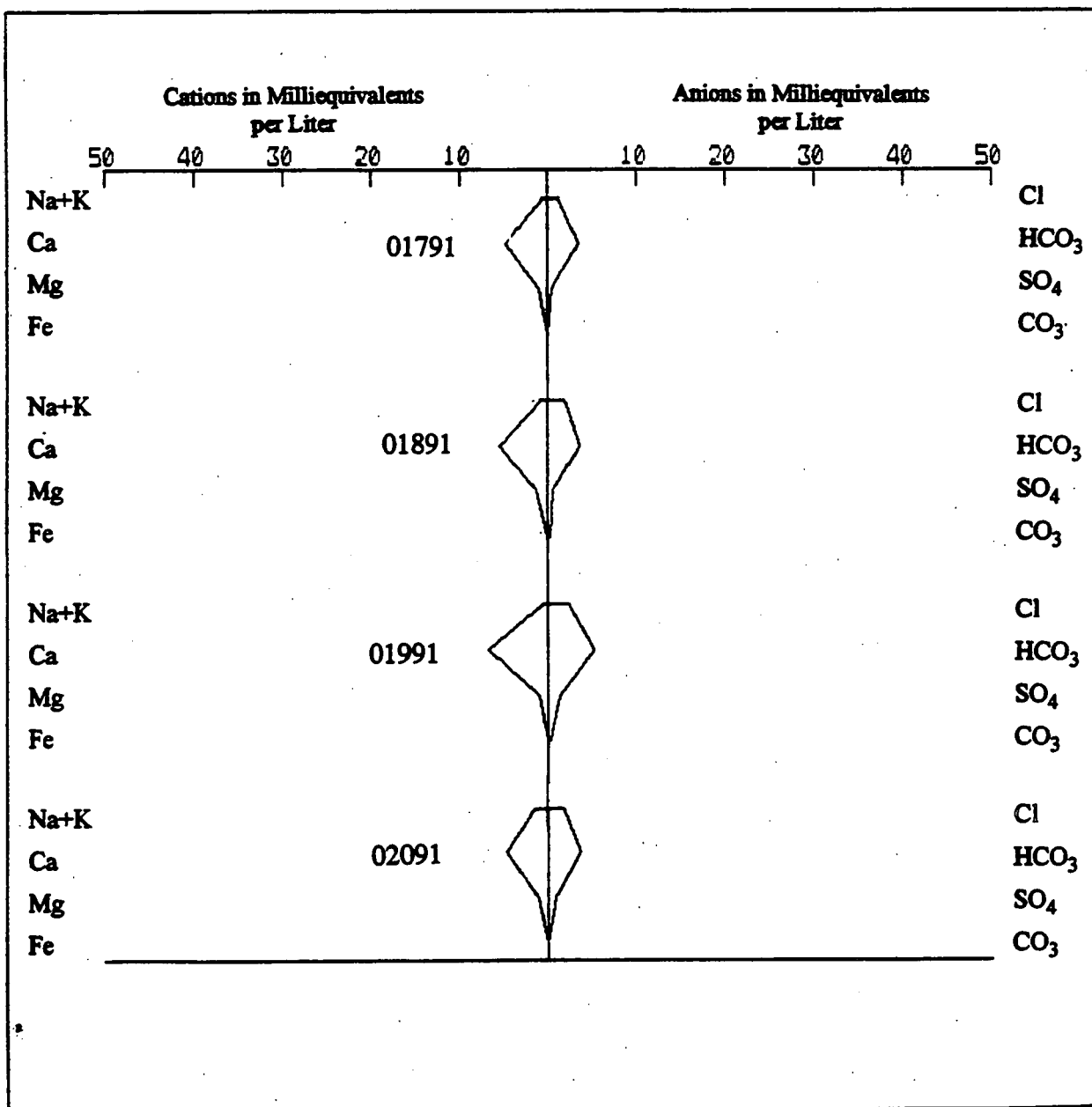
The relative sizes of Stiff diagrams are meaningful in that, the higher the TDS content of the water, the larger the area of the diagram (providing that the scale of display remains constant). The shape of the Stiff diagram also conveys useful information, particularly for use as a pattern-recognition tool. The shape is determined by the concentrations of four major metals (Ca, Mg, K, Na) and four important anions ( $\text{HCO}_3$ ,  $\text{CO}_3$ , Cl,  $\text{SO}_4$ ), expressed in units of milliequivalents per liter (meq/L).

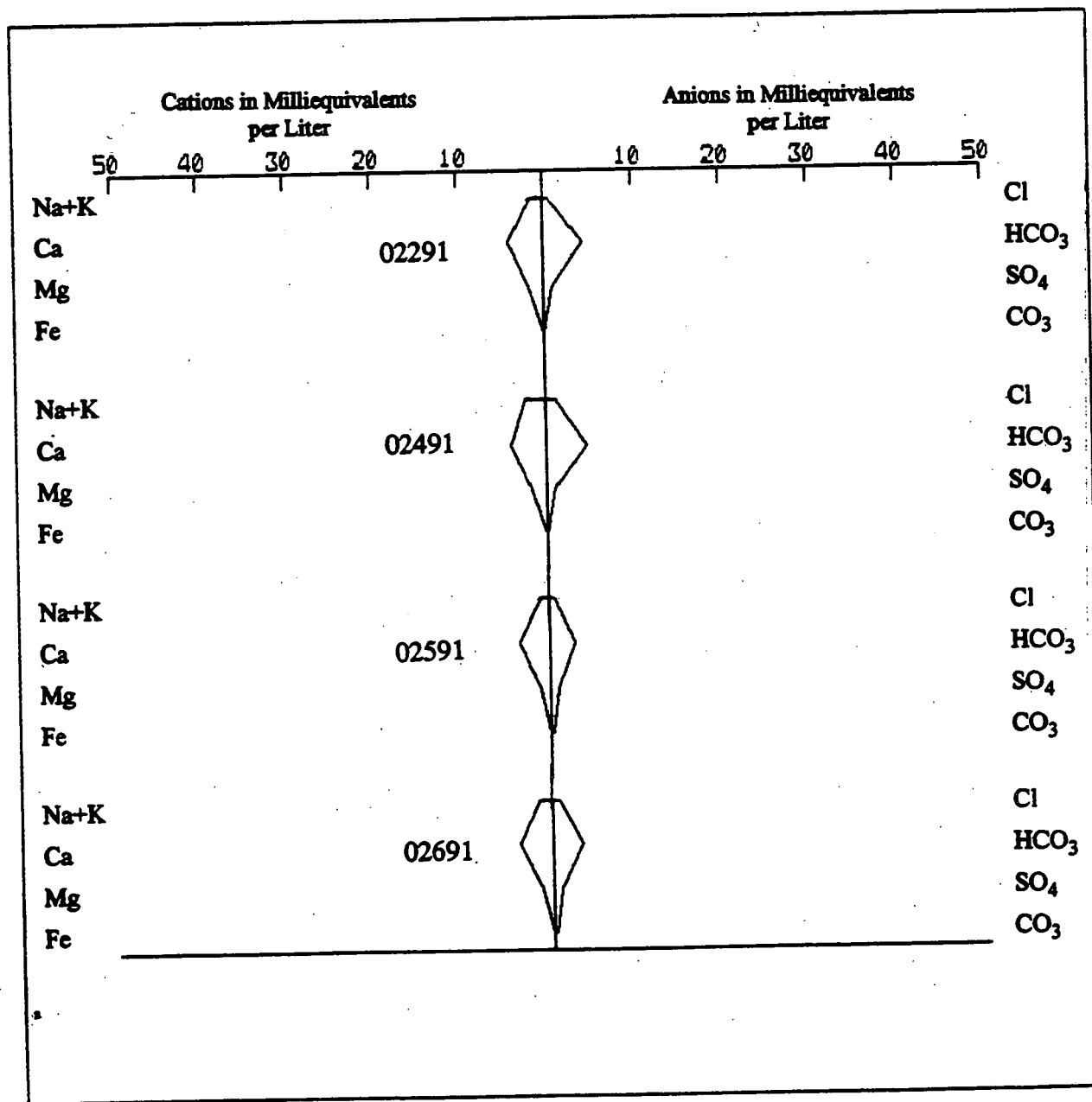
Stiff diagrams can be useful for understanding the evolution in major-ion chemistry along a groundwater flow path. There are a number of factors that affect groundwater chemistry along a flow path, including ion-exchange reactions, oxidation/reduction reactions, and mineral dissolution/precipitation processes. Also, in downgradient areas, some changes in chemistry may be the result of local groundwater contamination. In addition, the groundwaters in different hydrostratigraphic units may have different major-ion chemistries, hence different sizes and shapes of Stiff plots that allow for quick visual recognition of the various groundwaters.



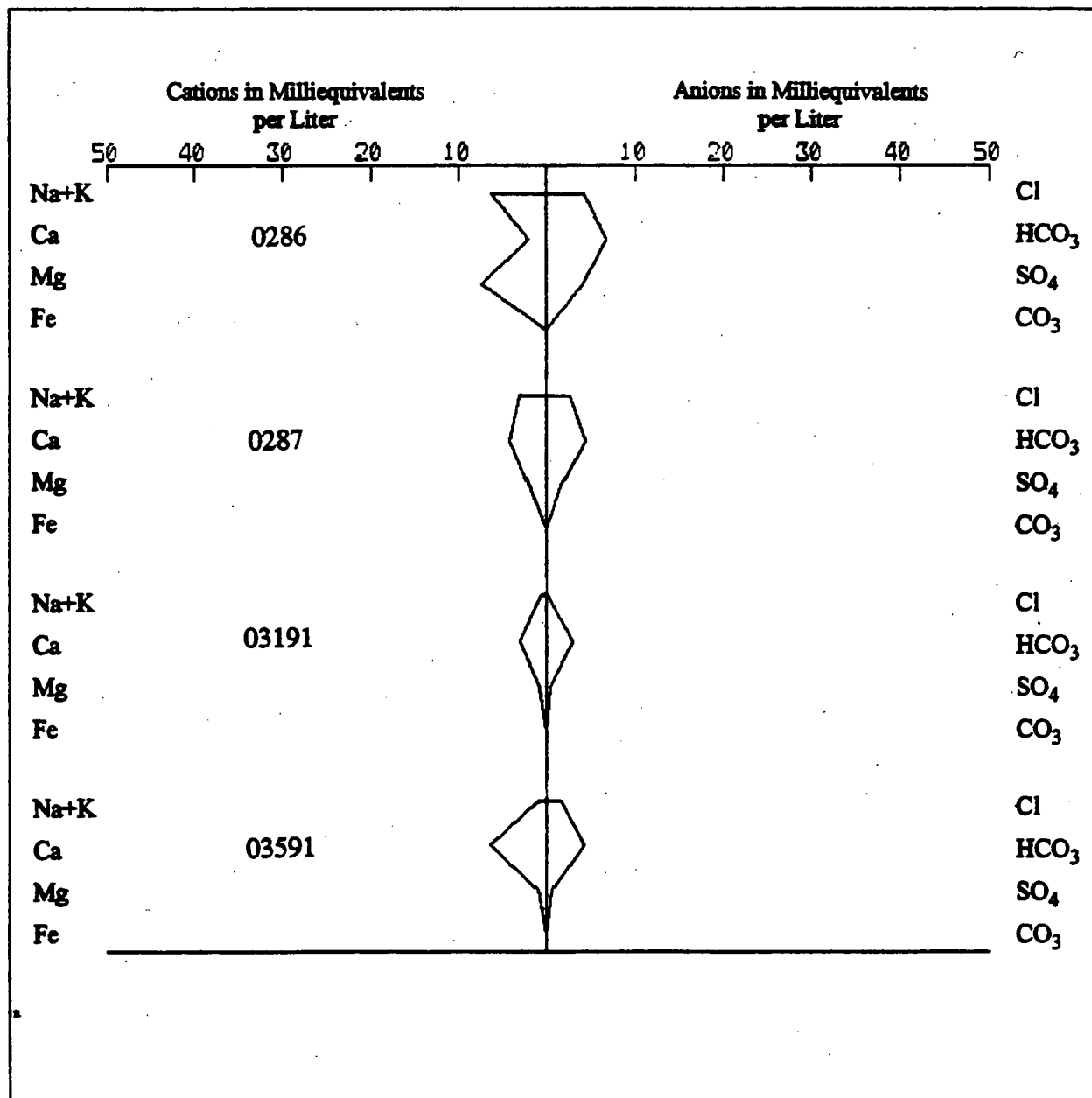


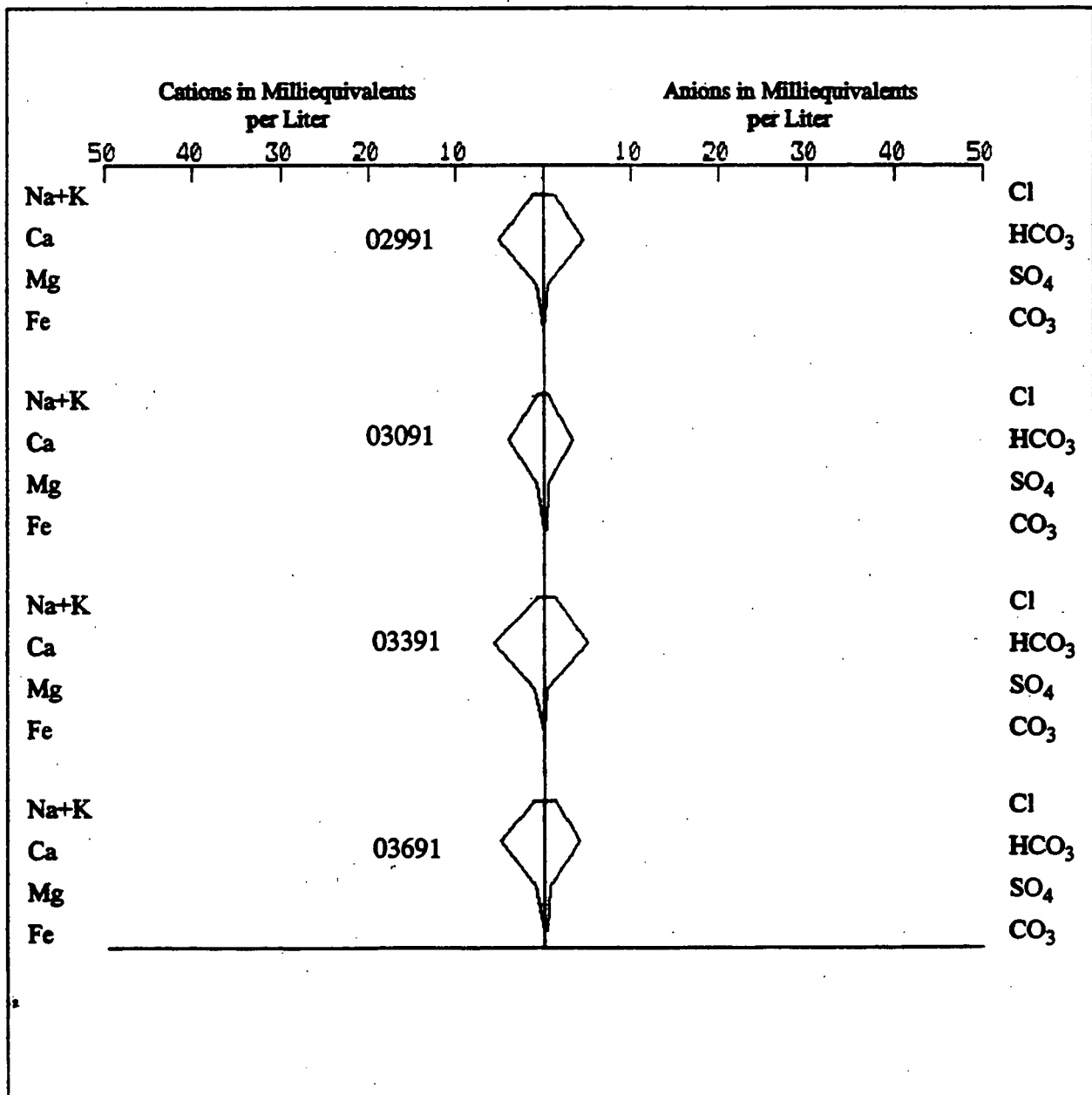




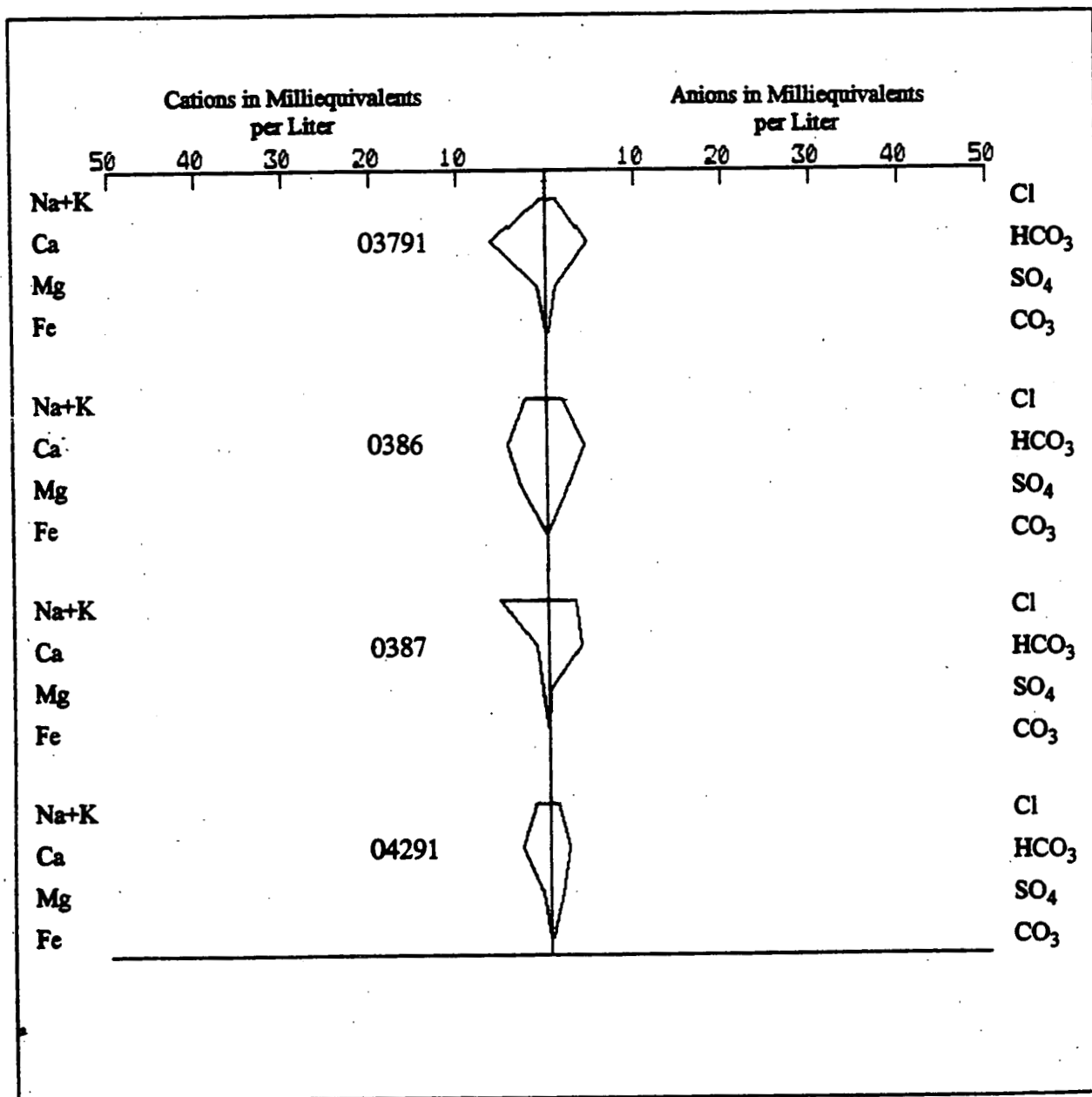


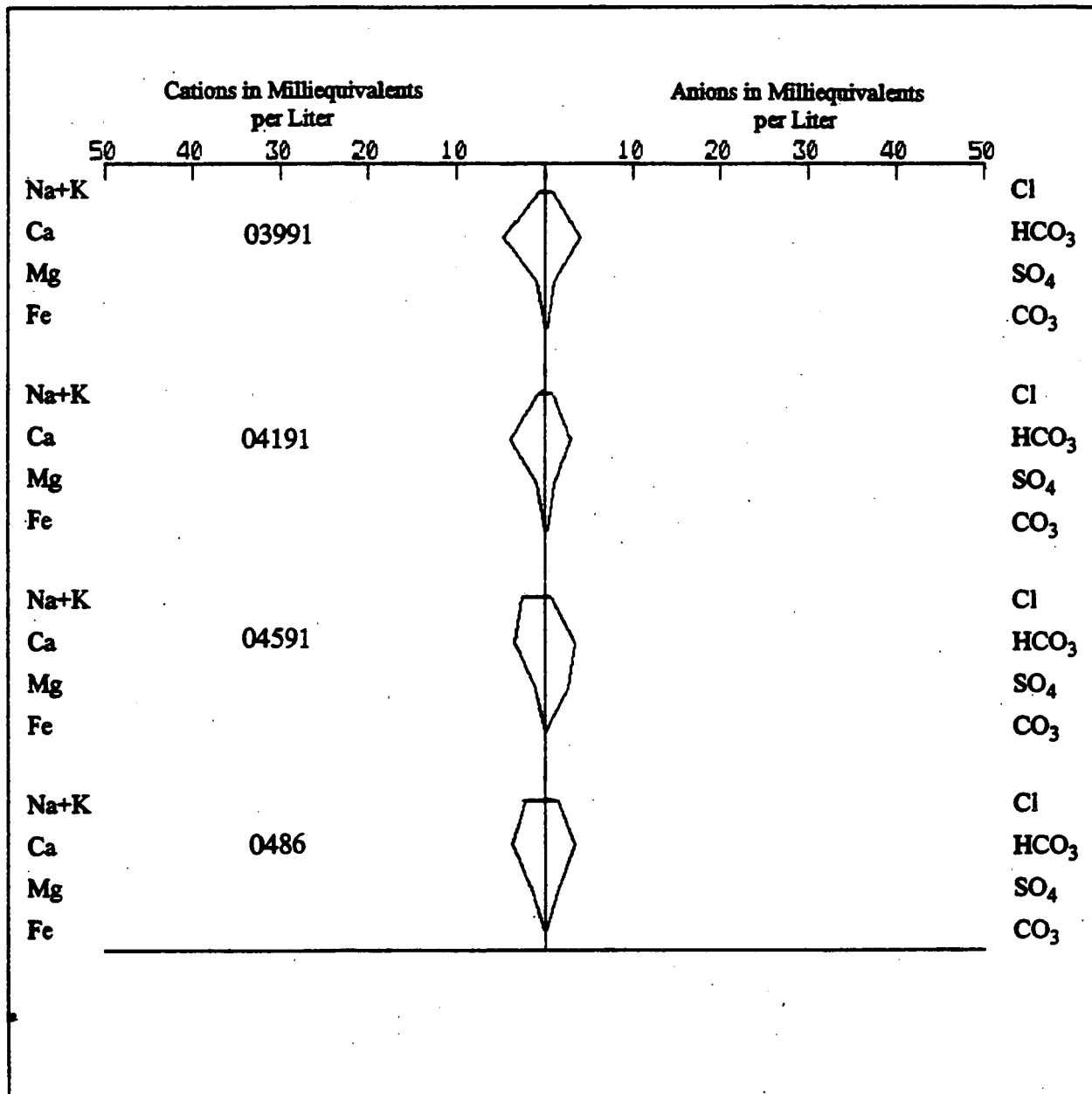
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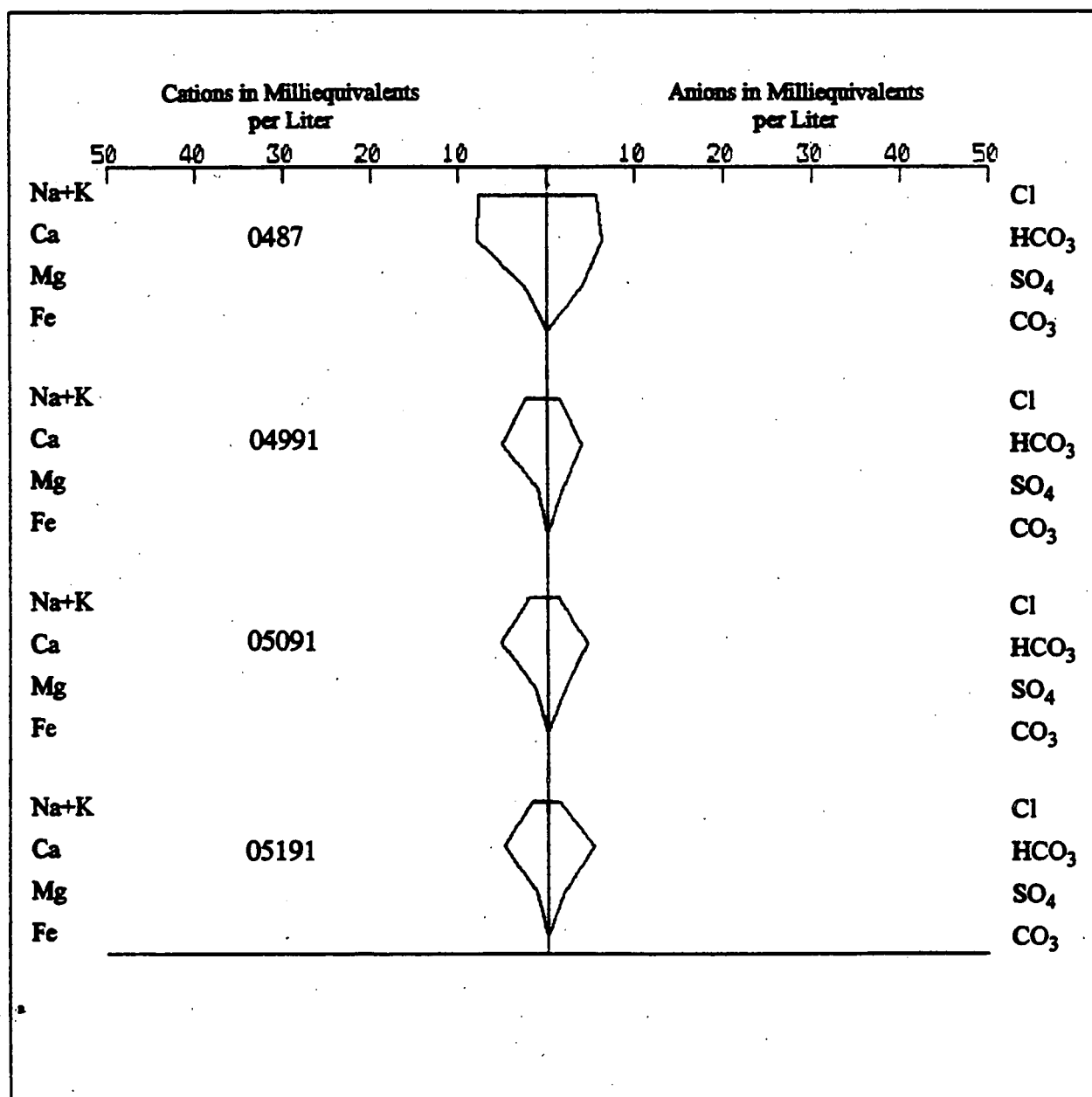
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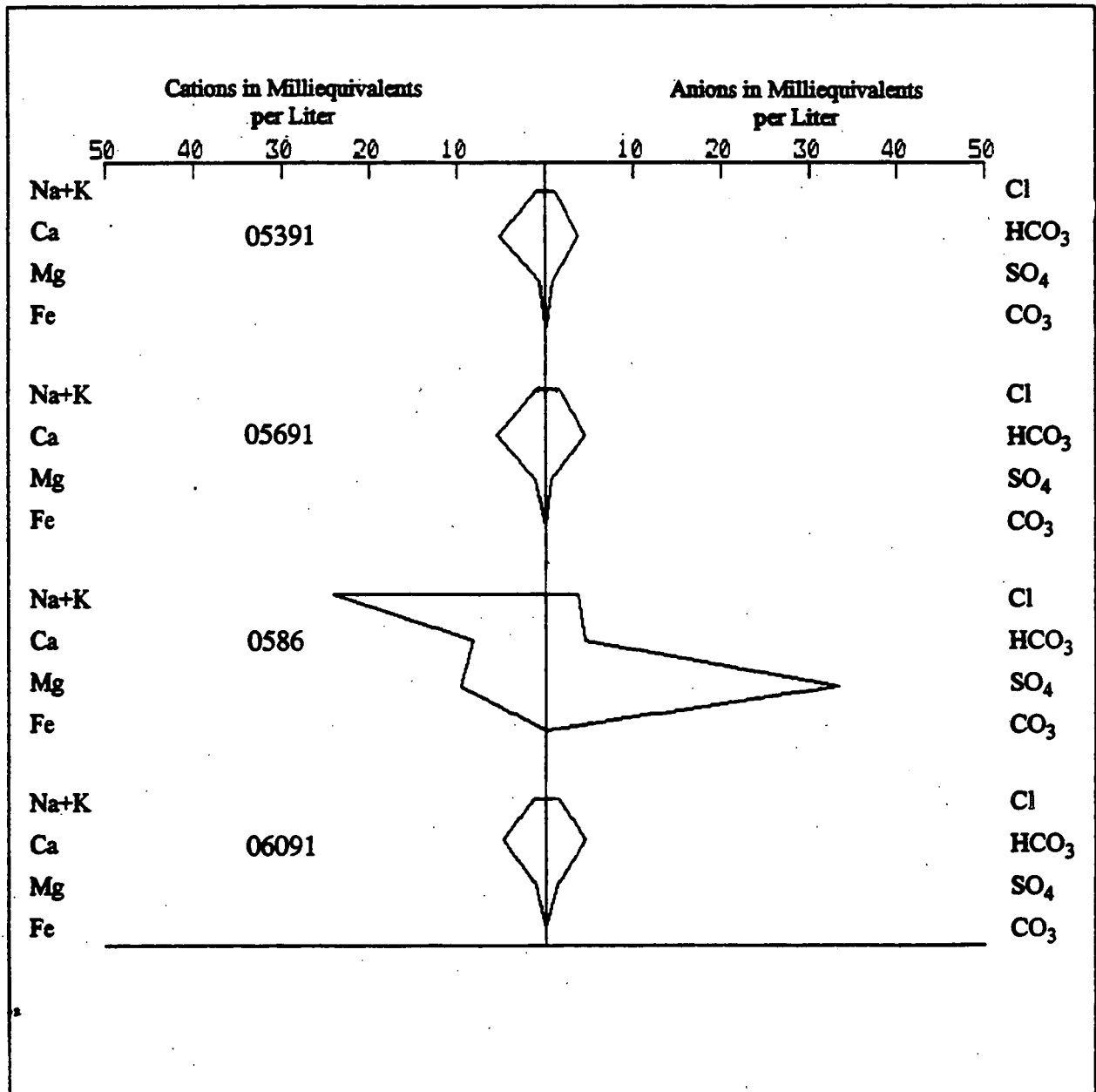


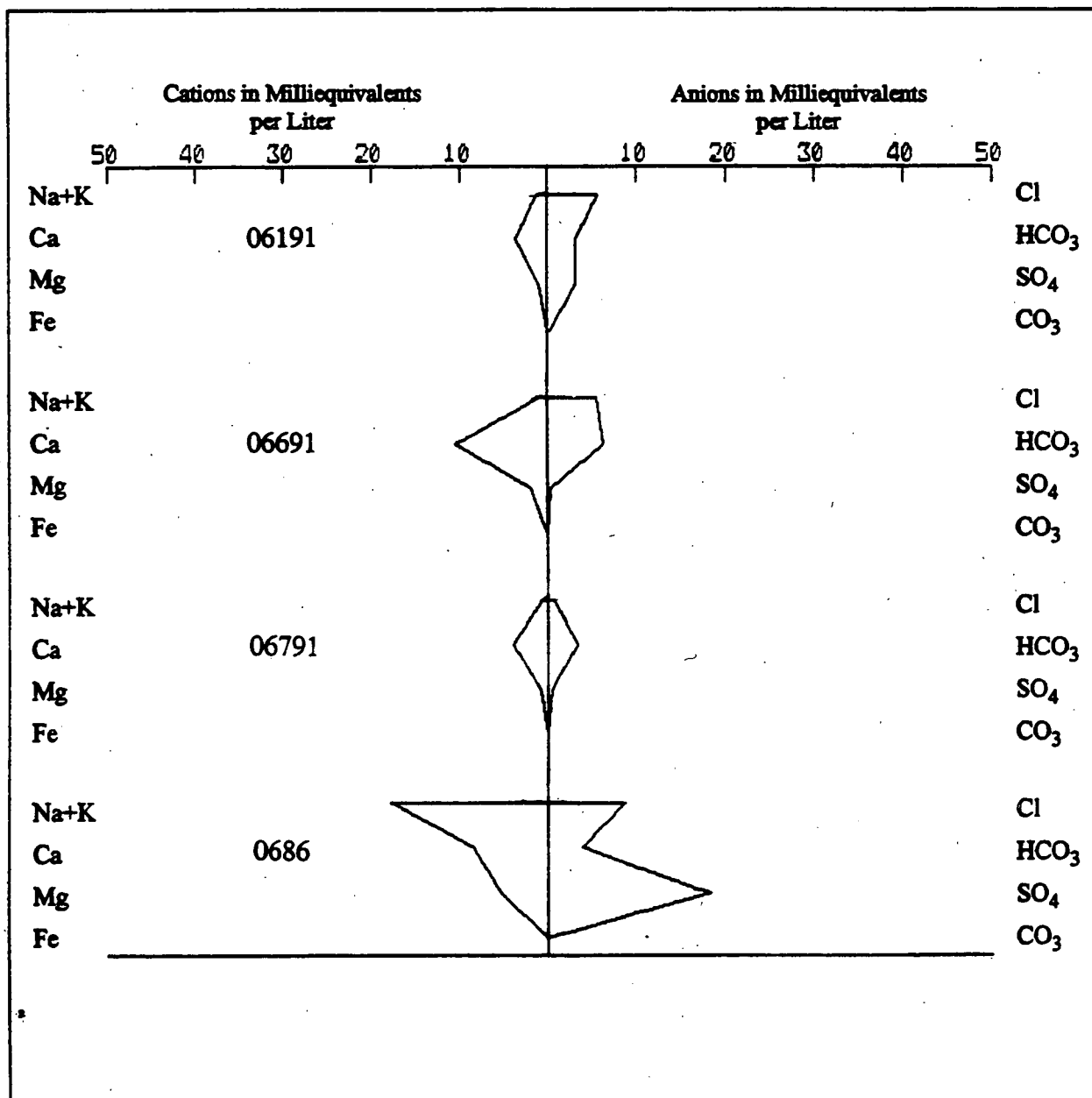
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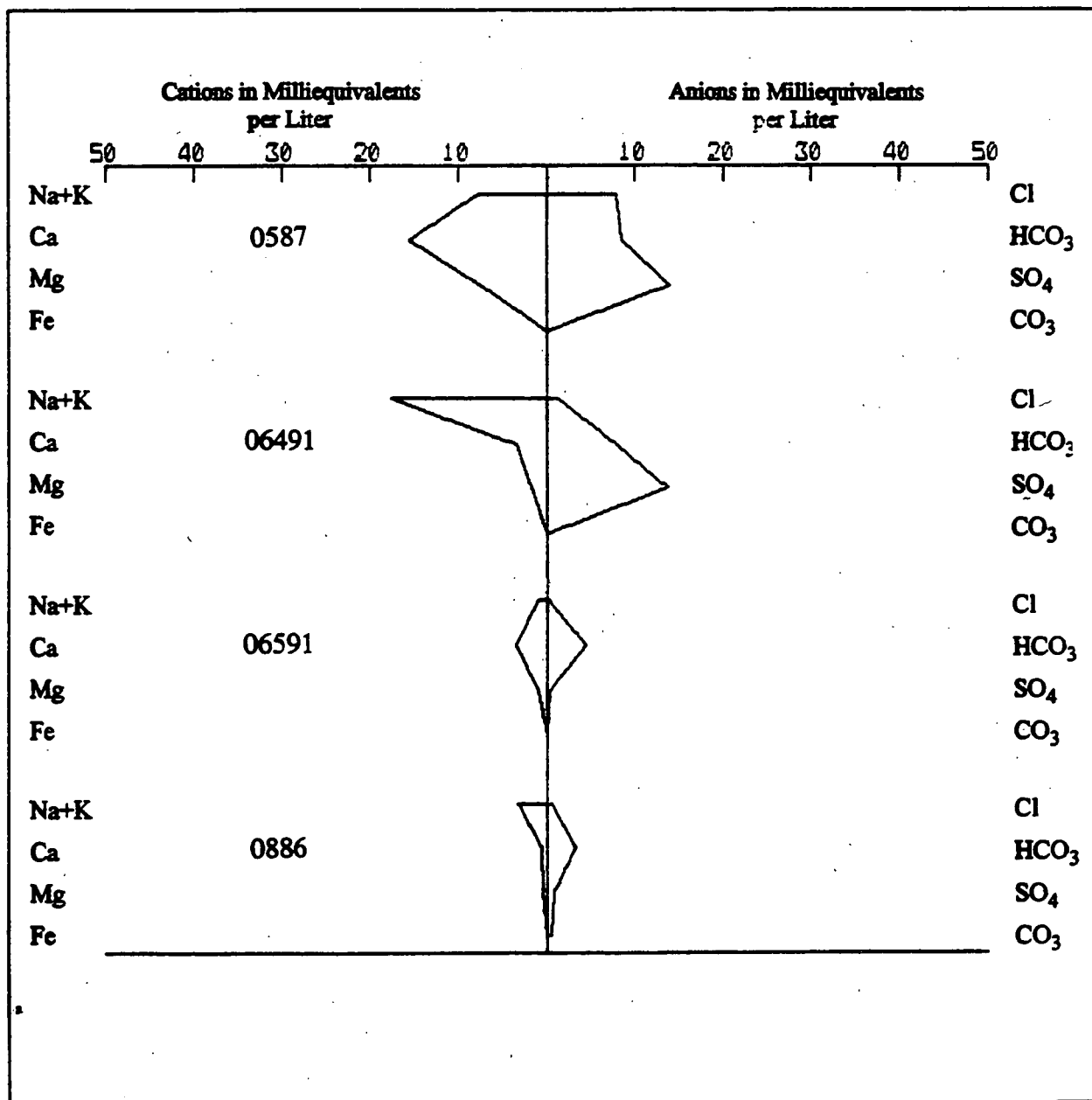


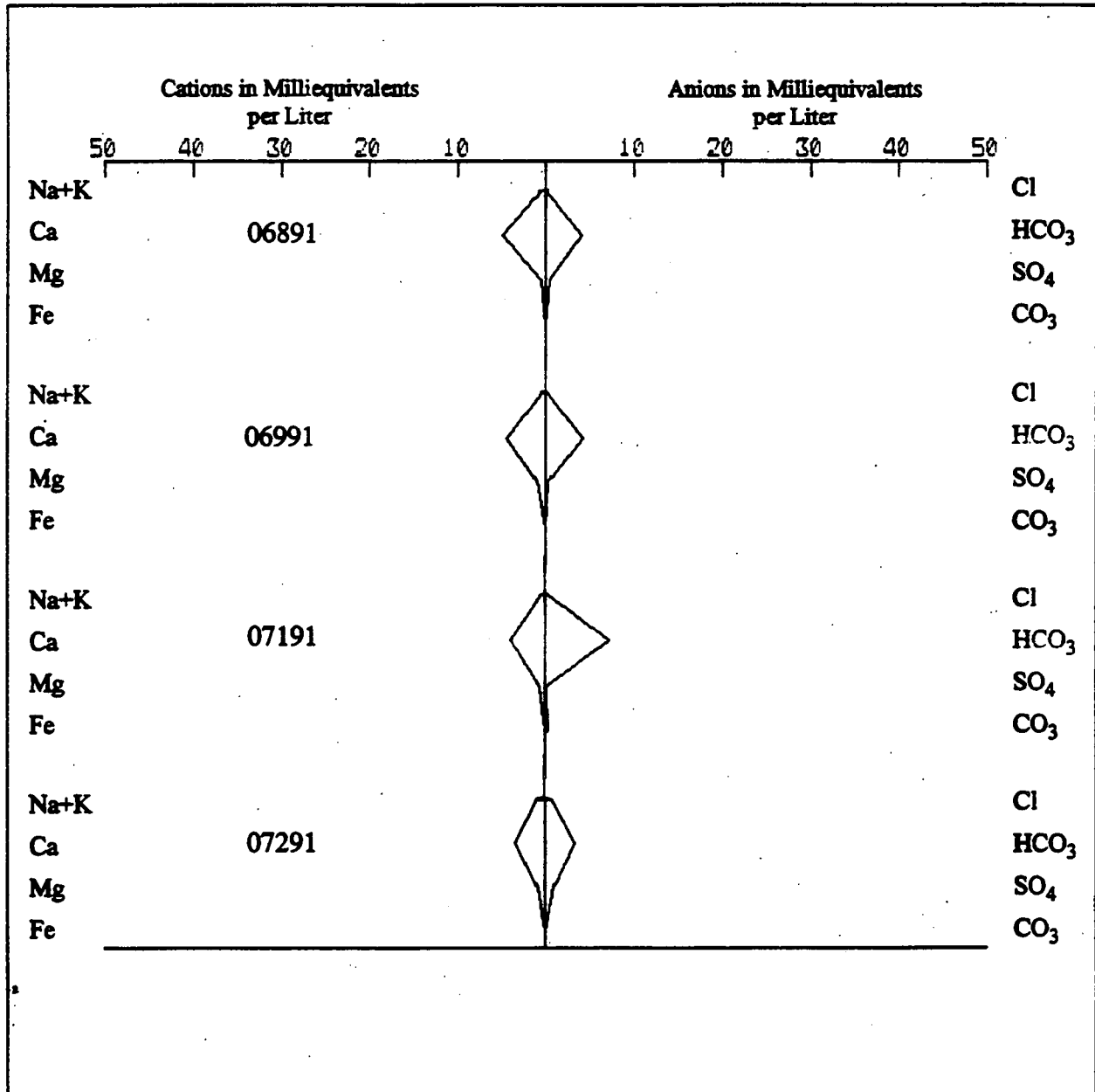


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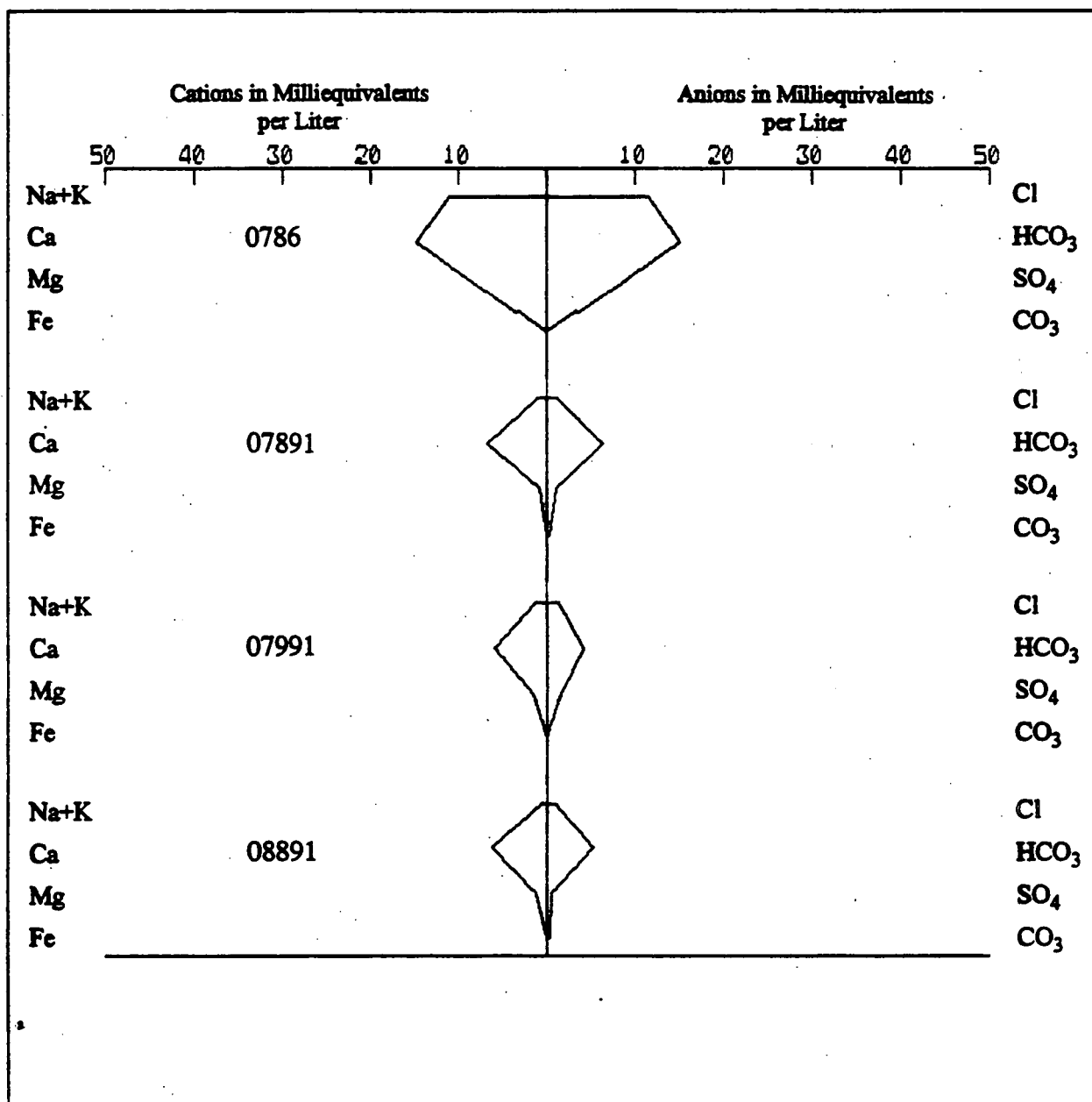




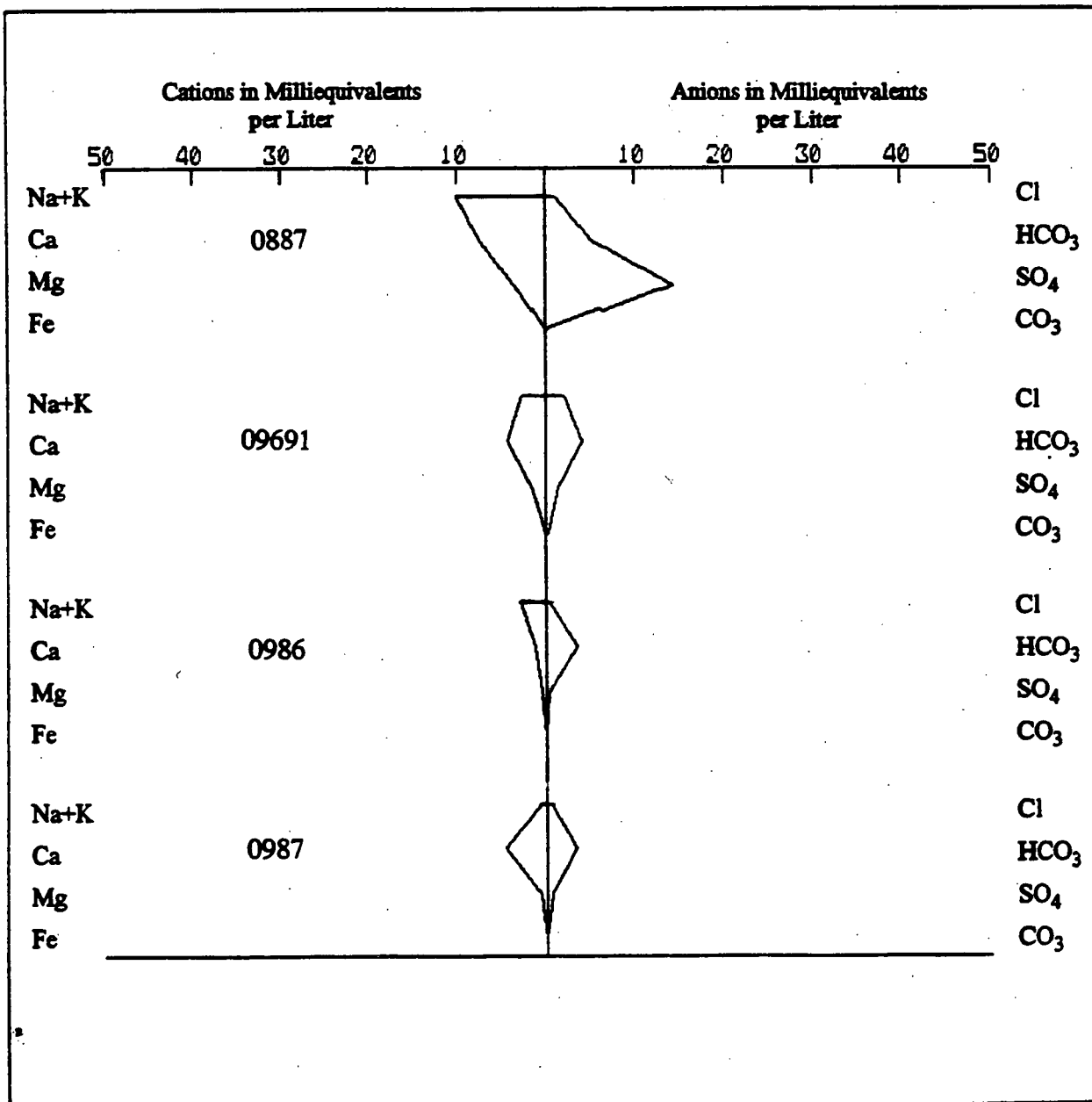




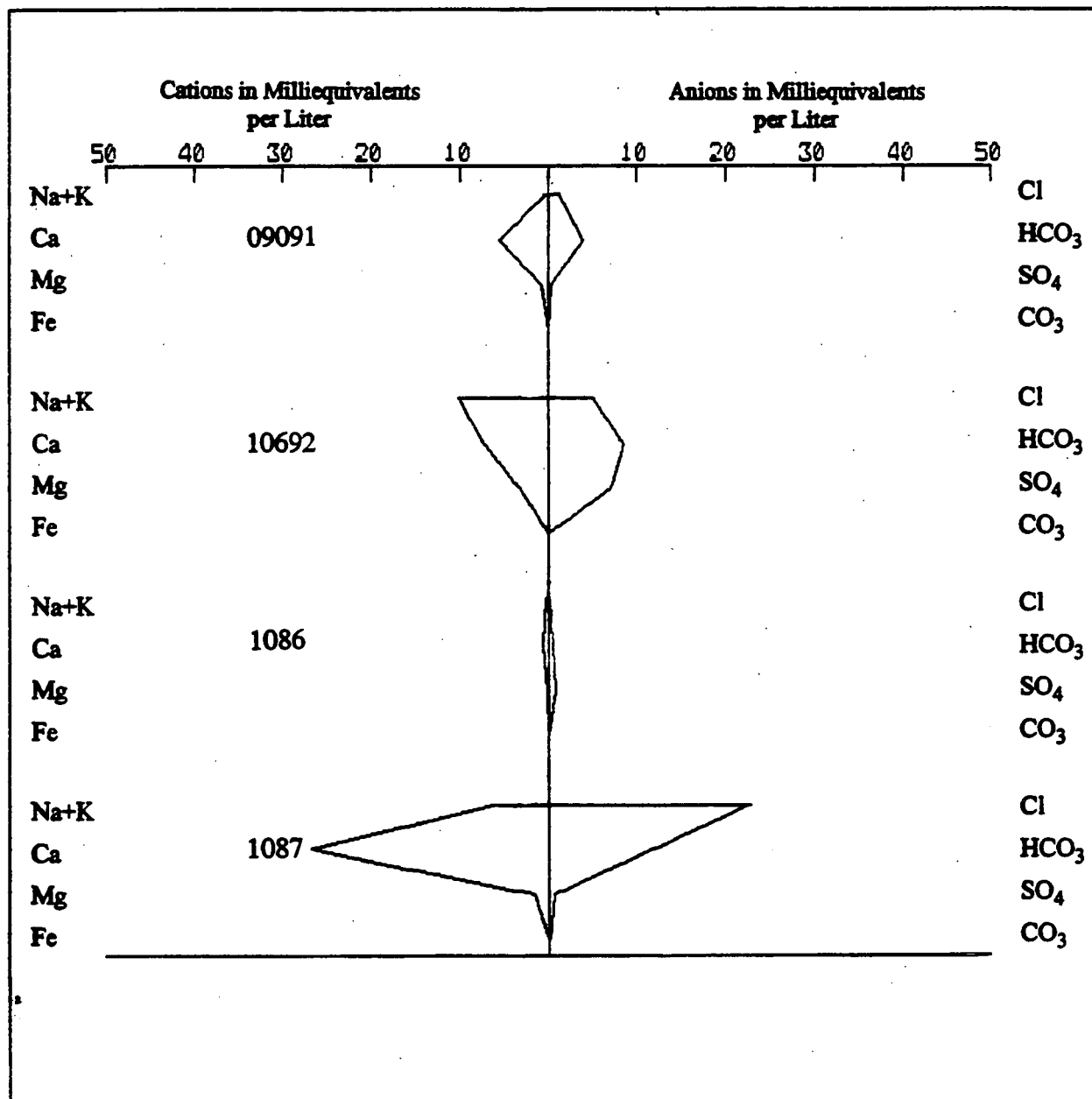
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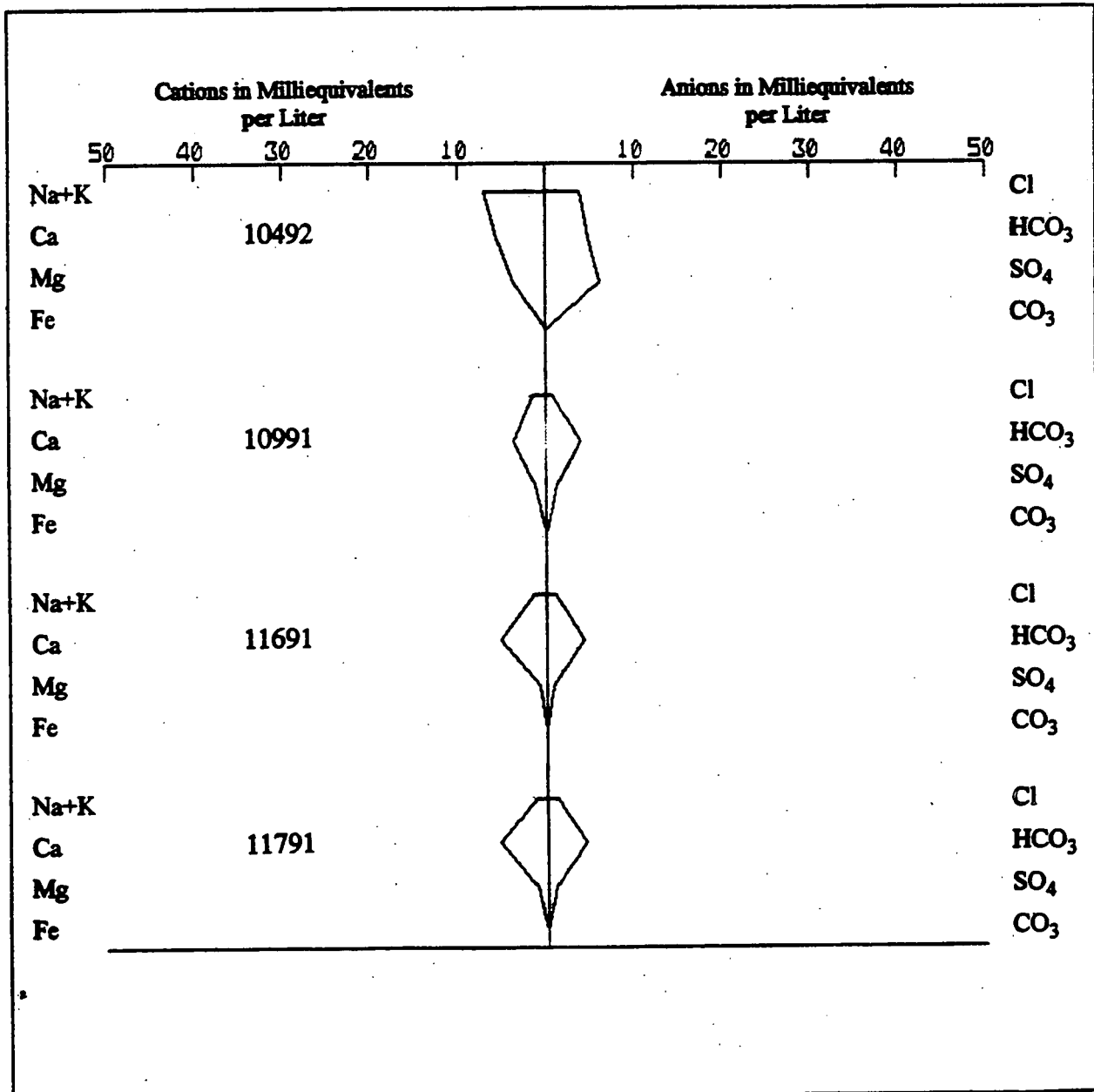
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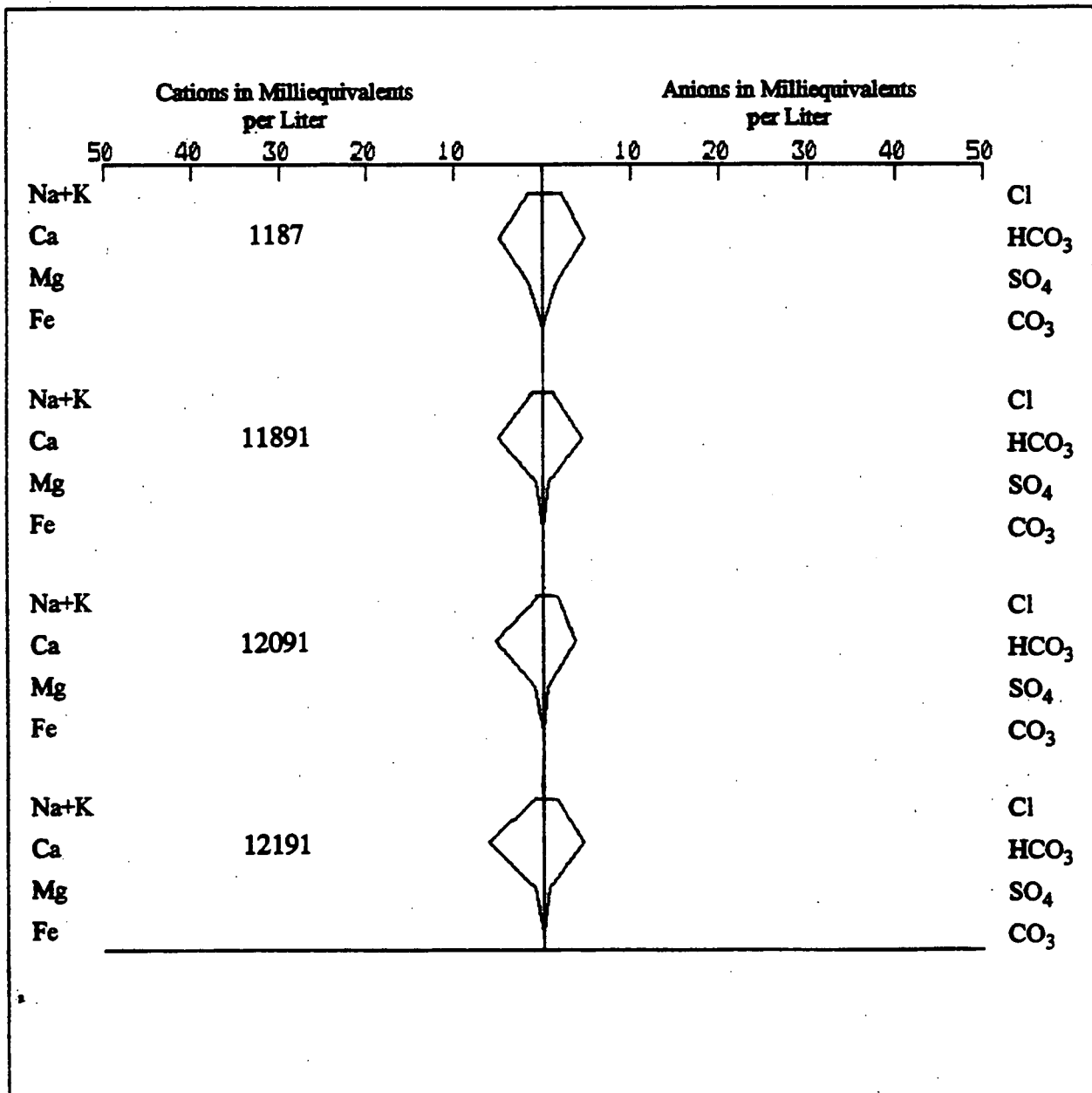
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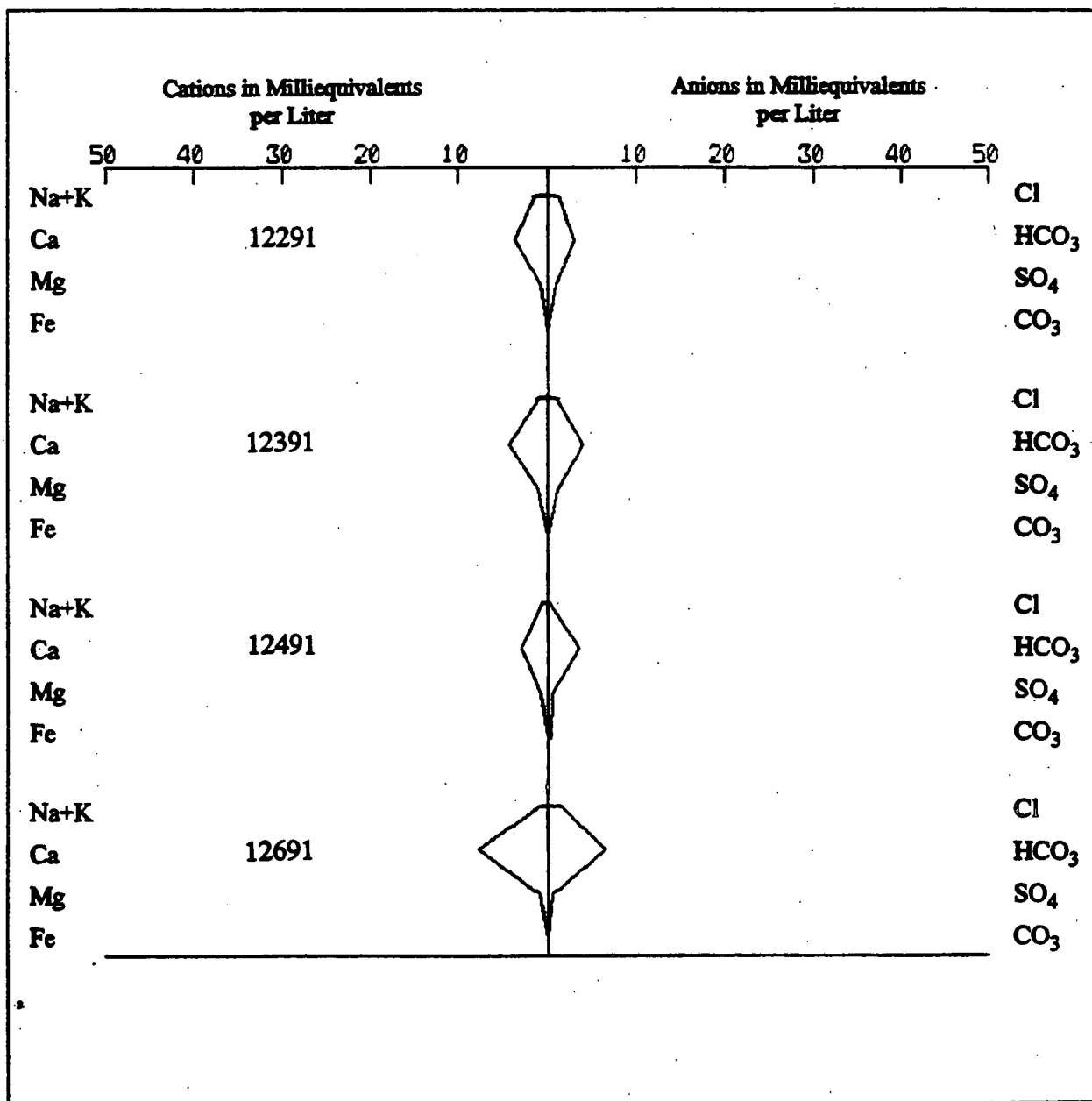


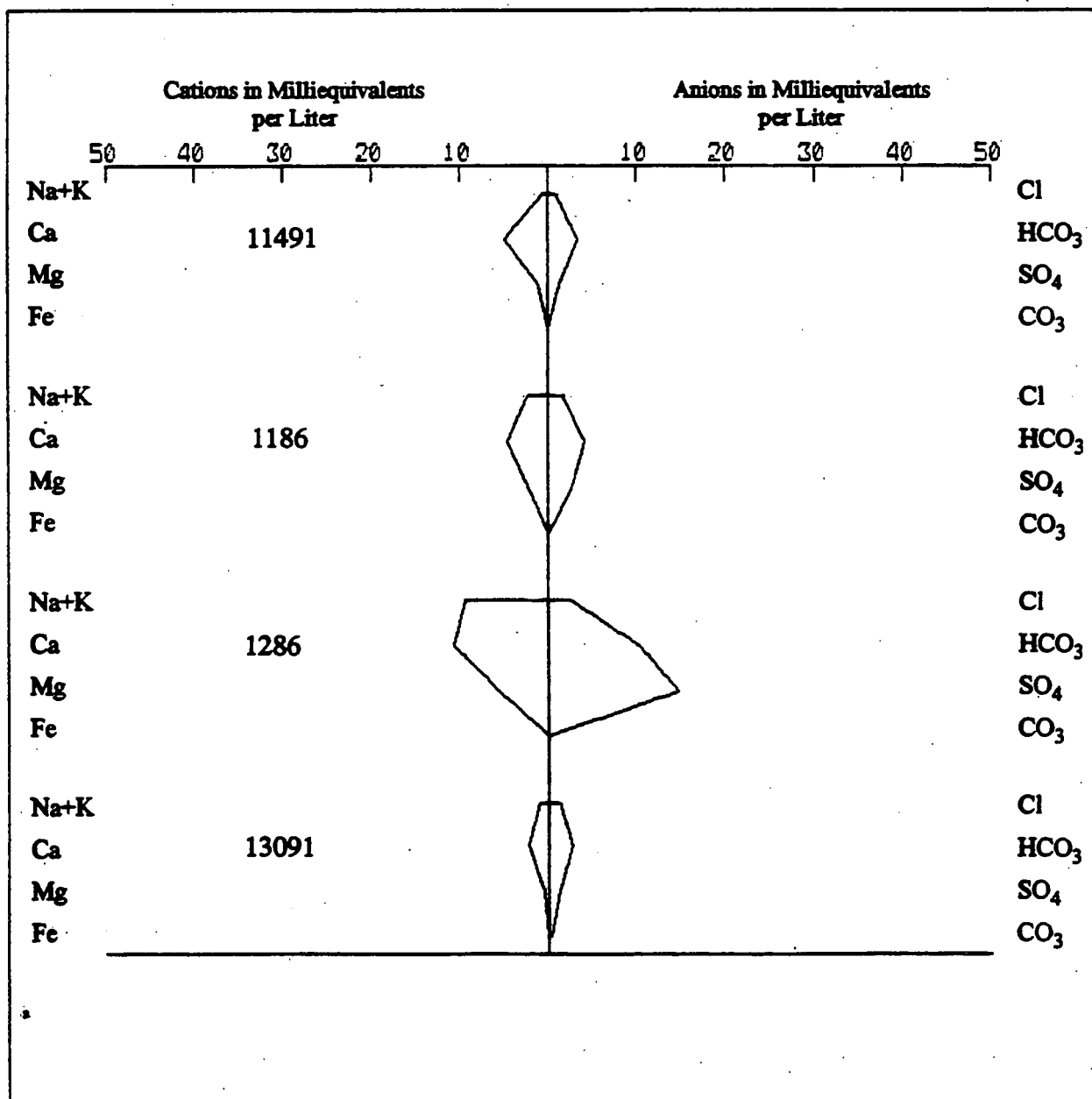


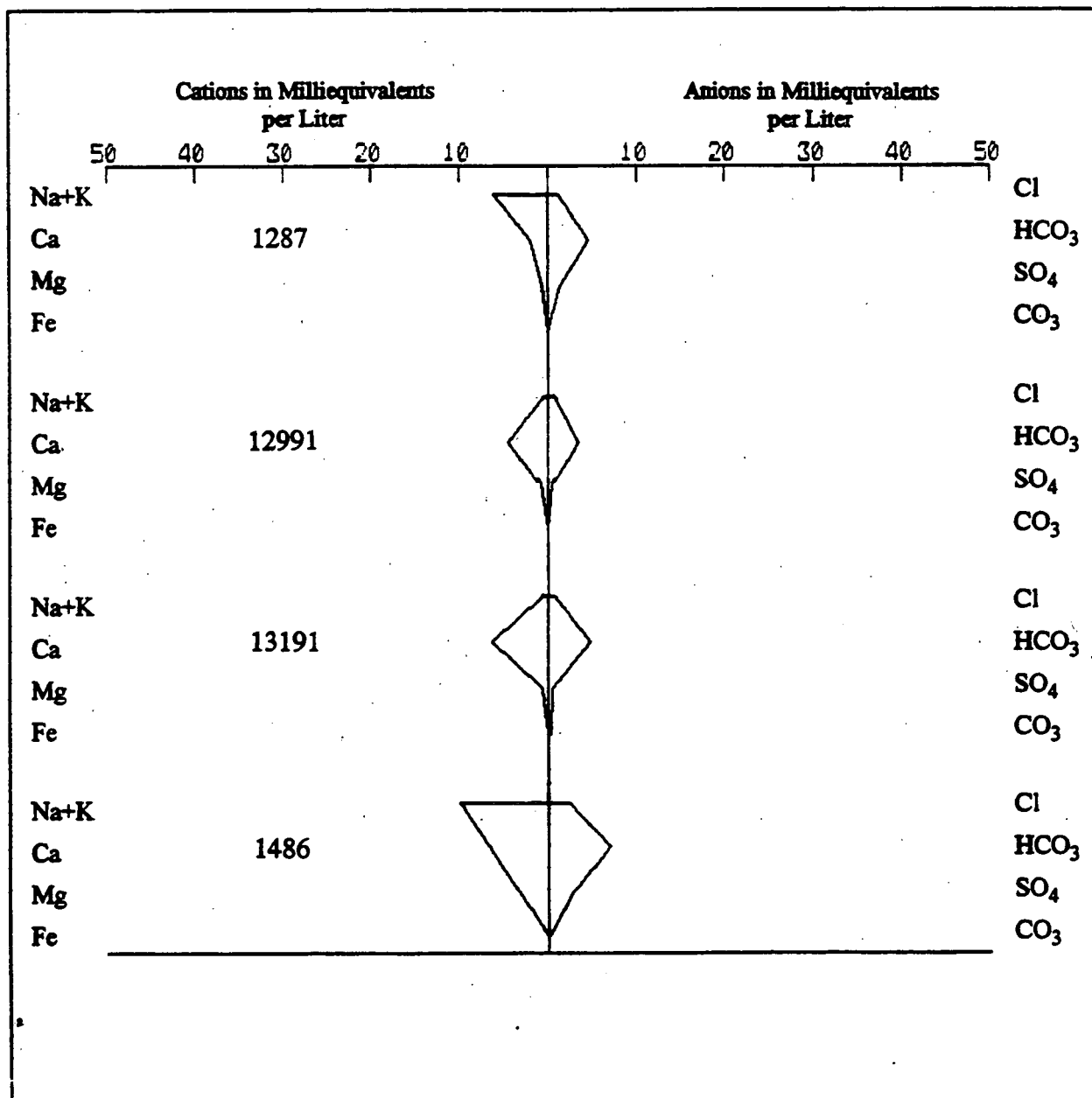


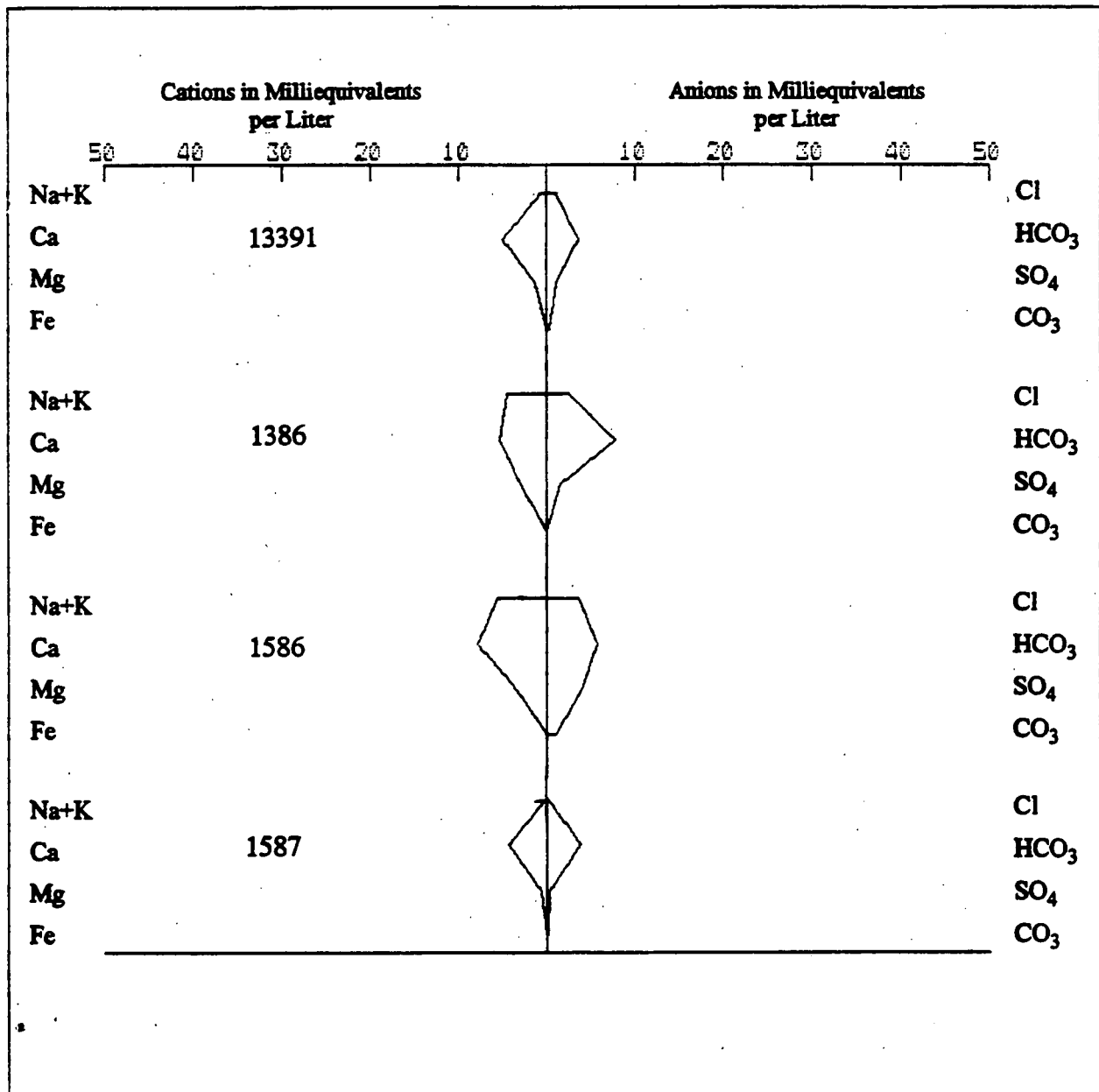
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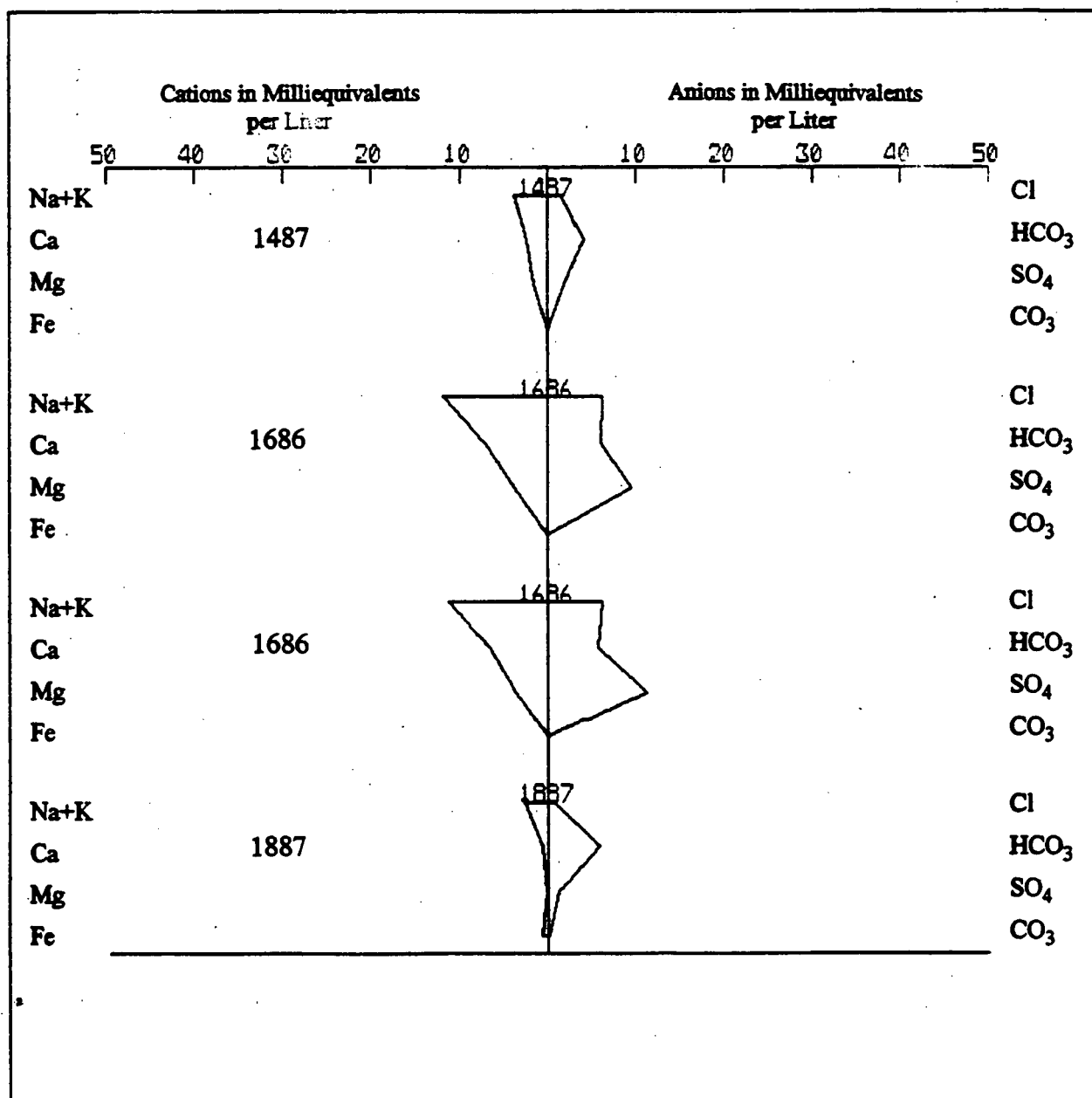




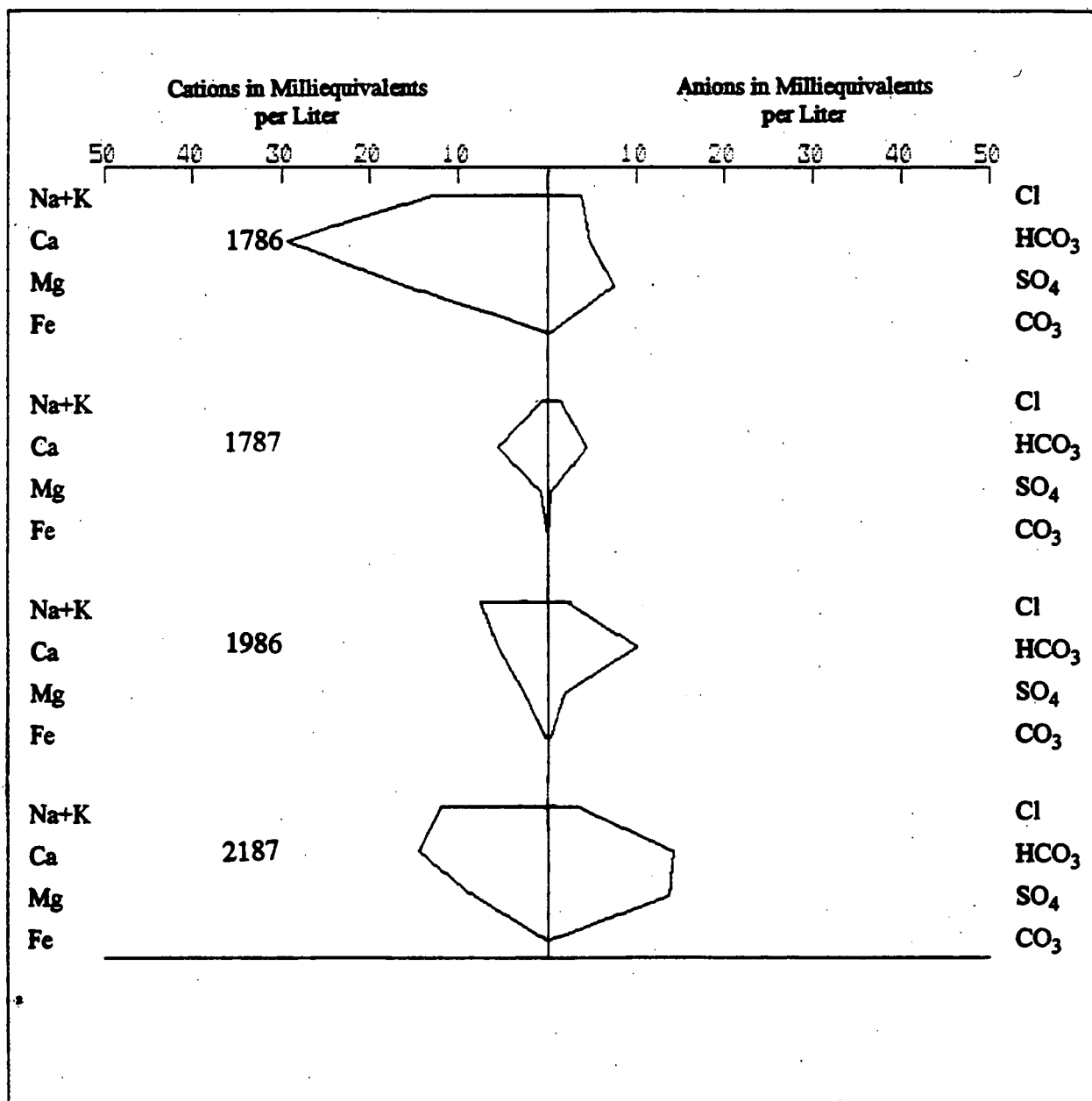




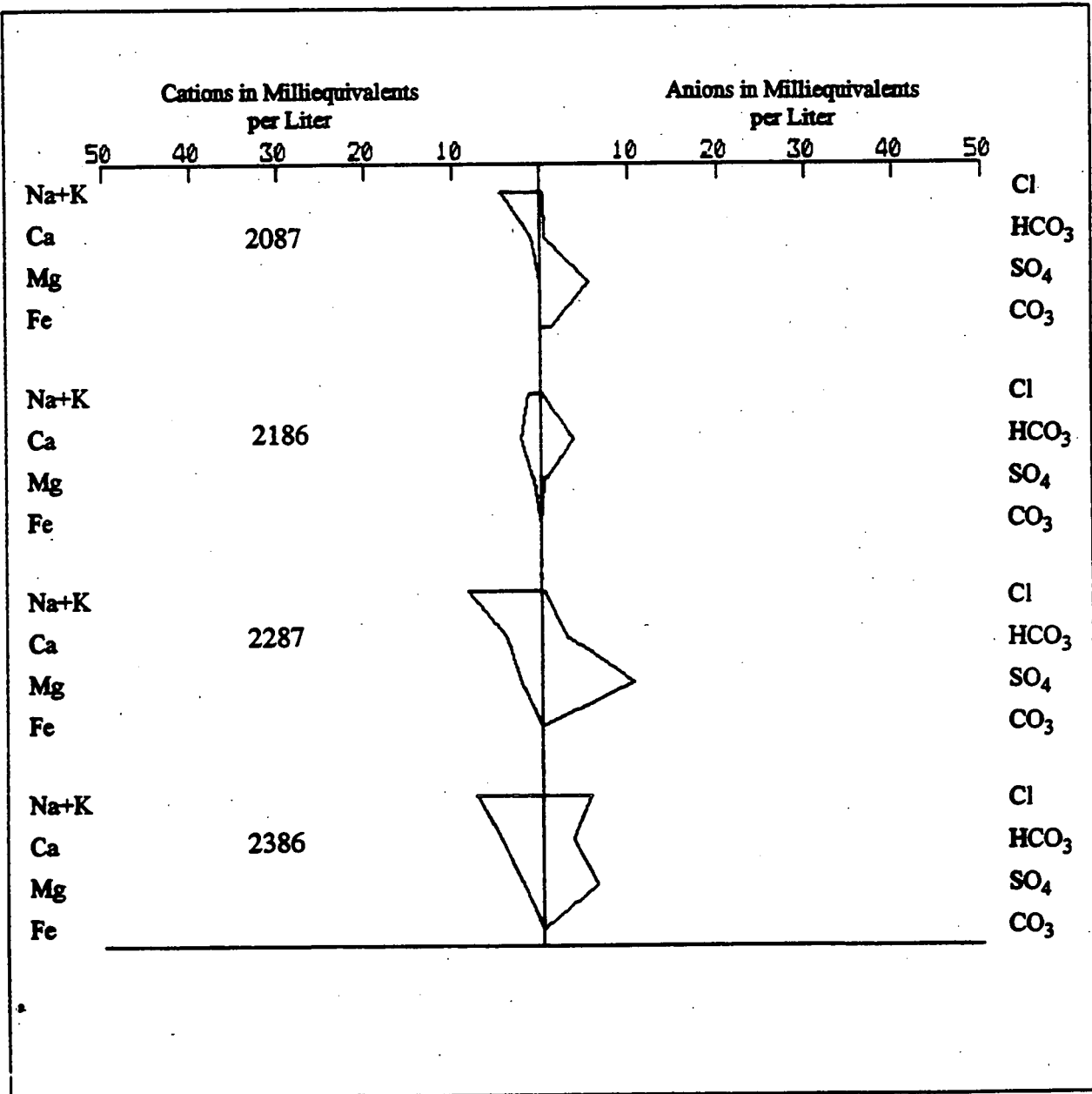
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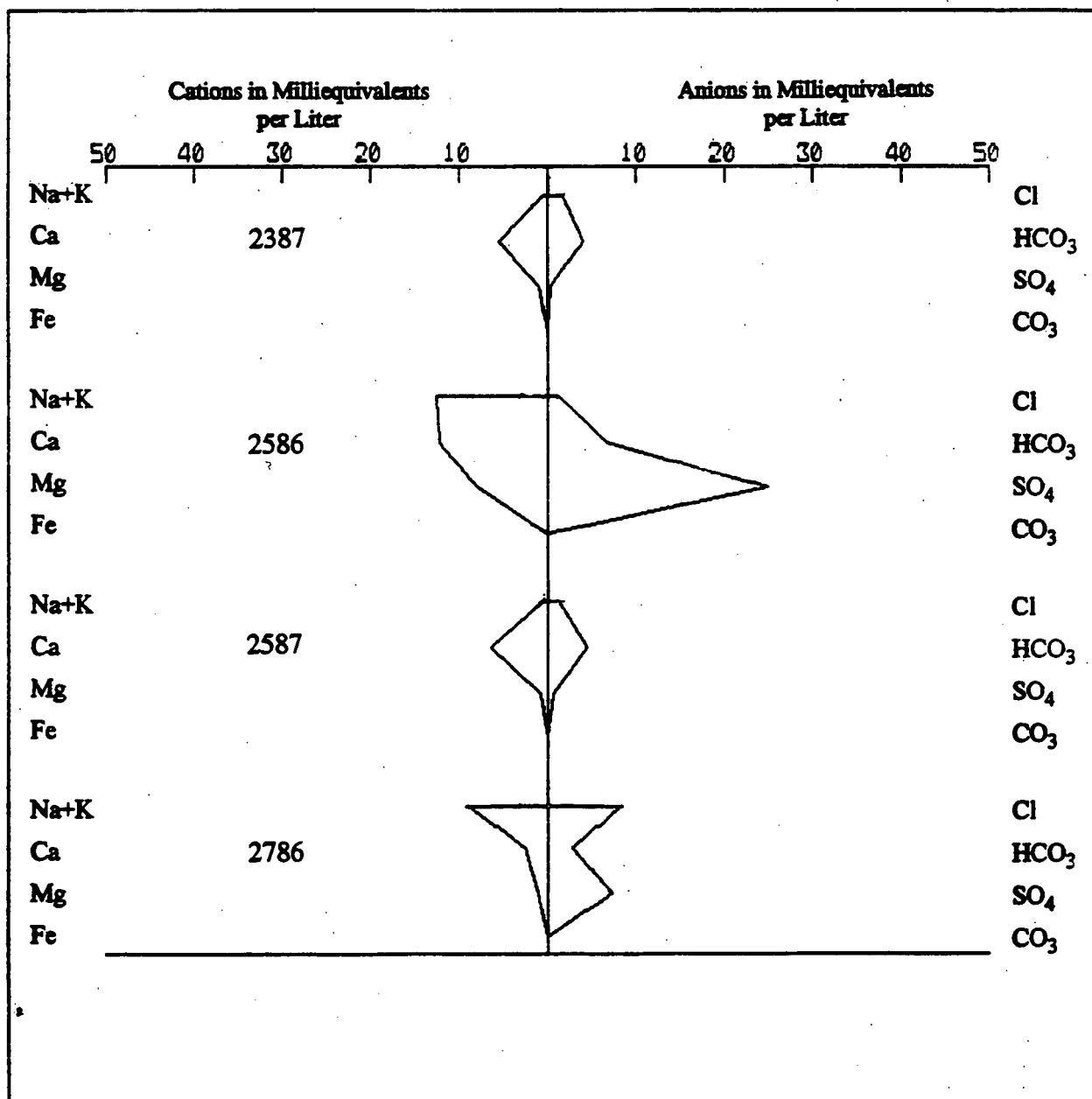
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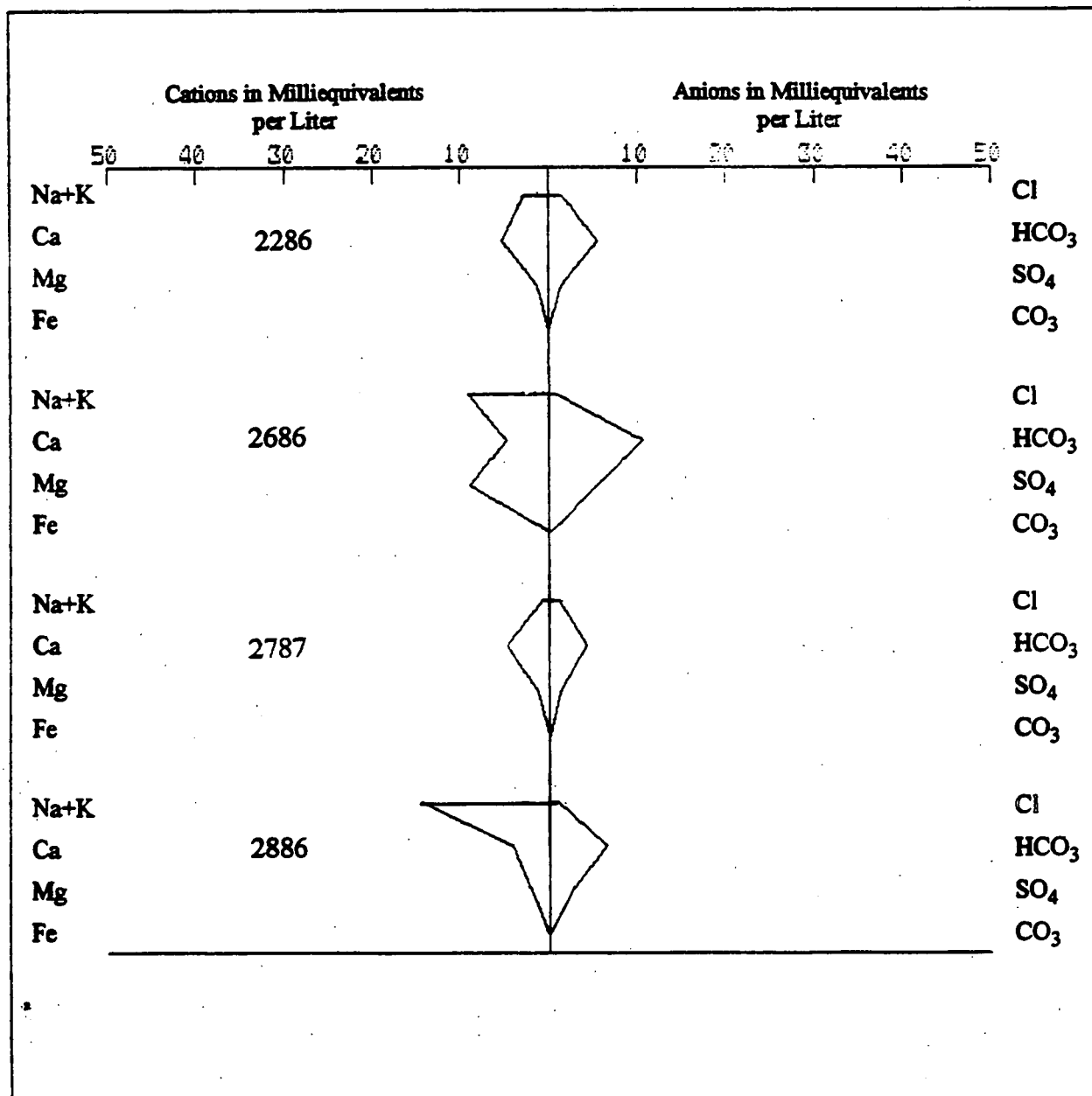


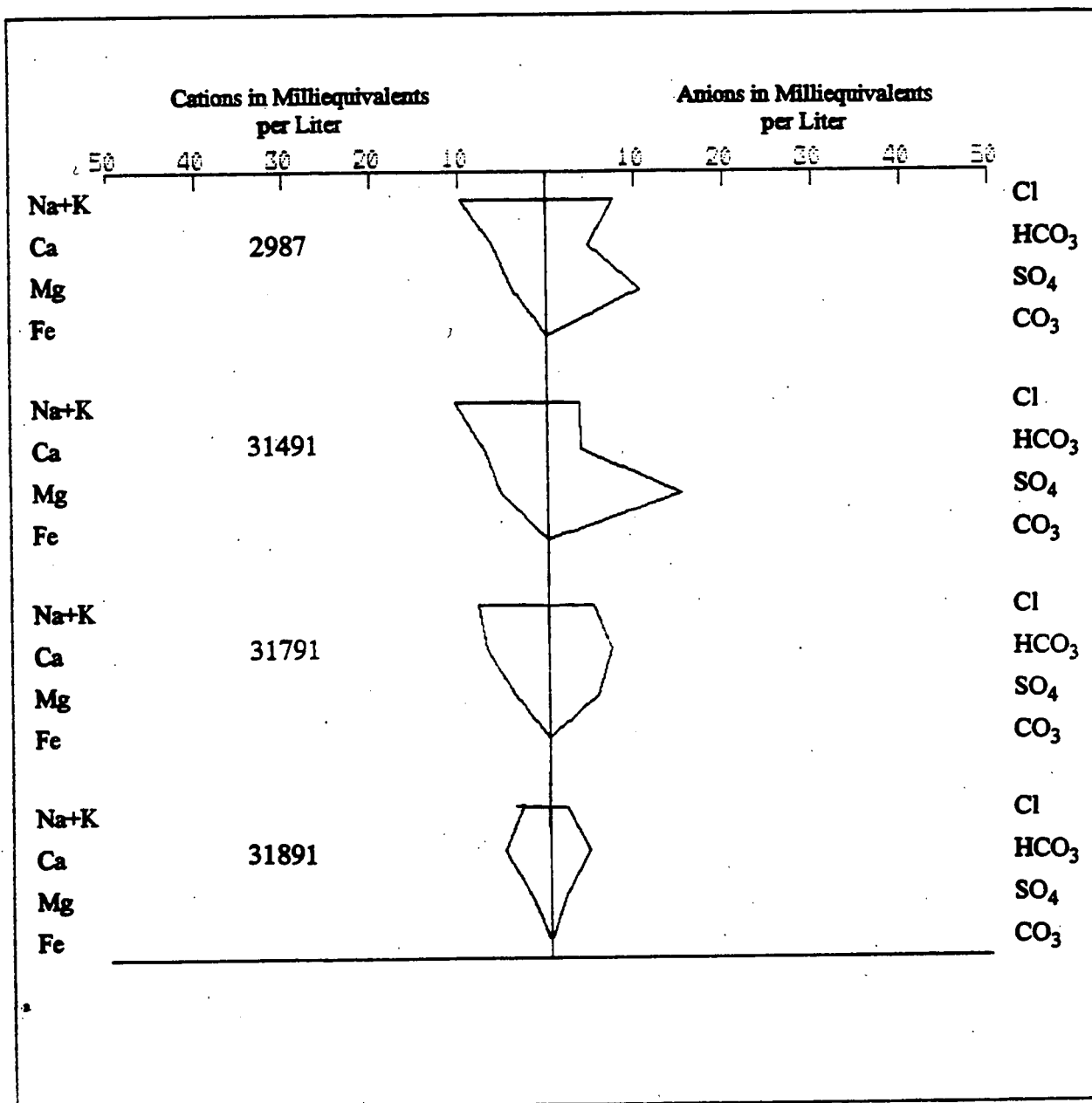


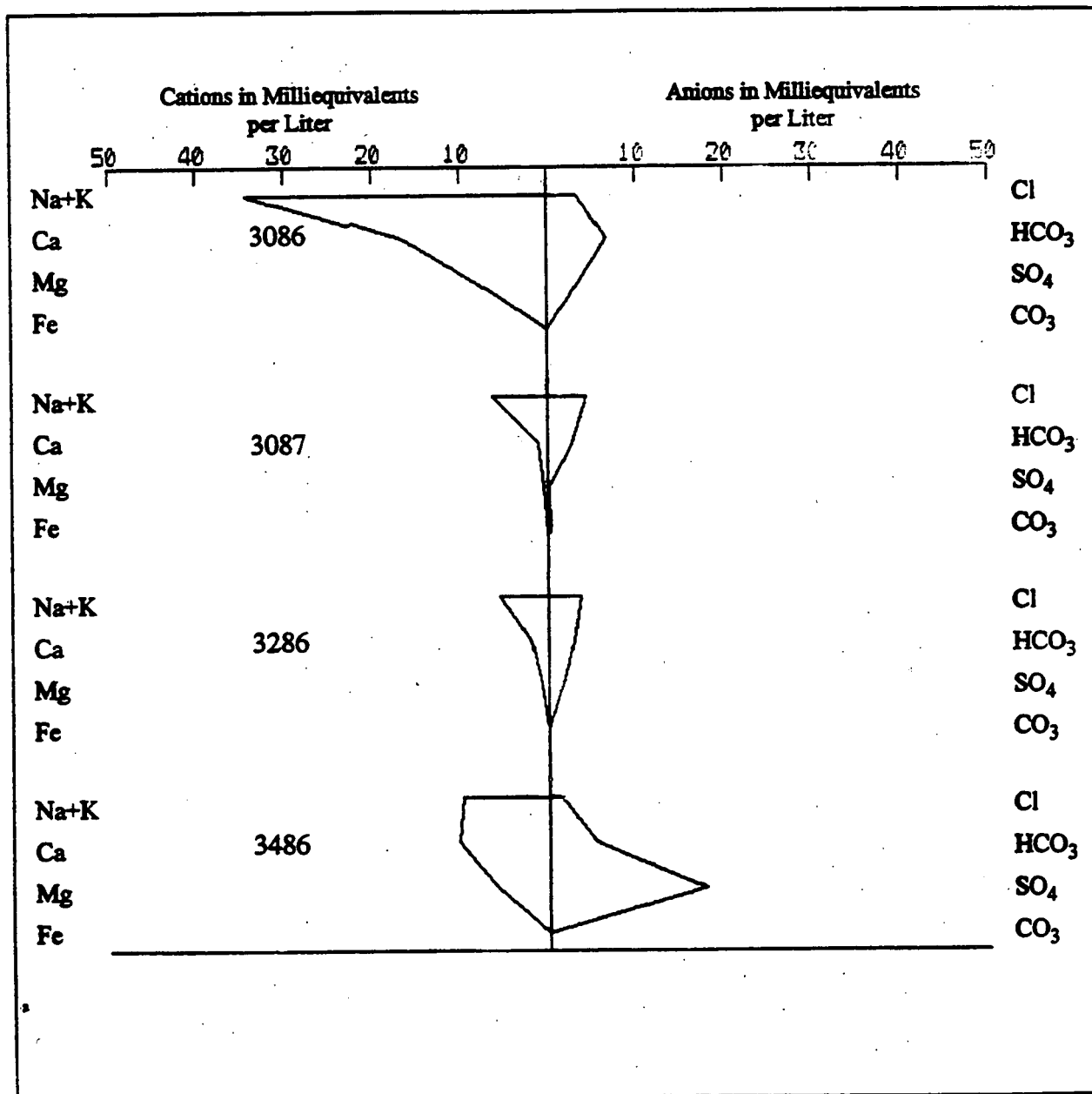


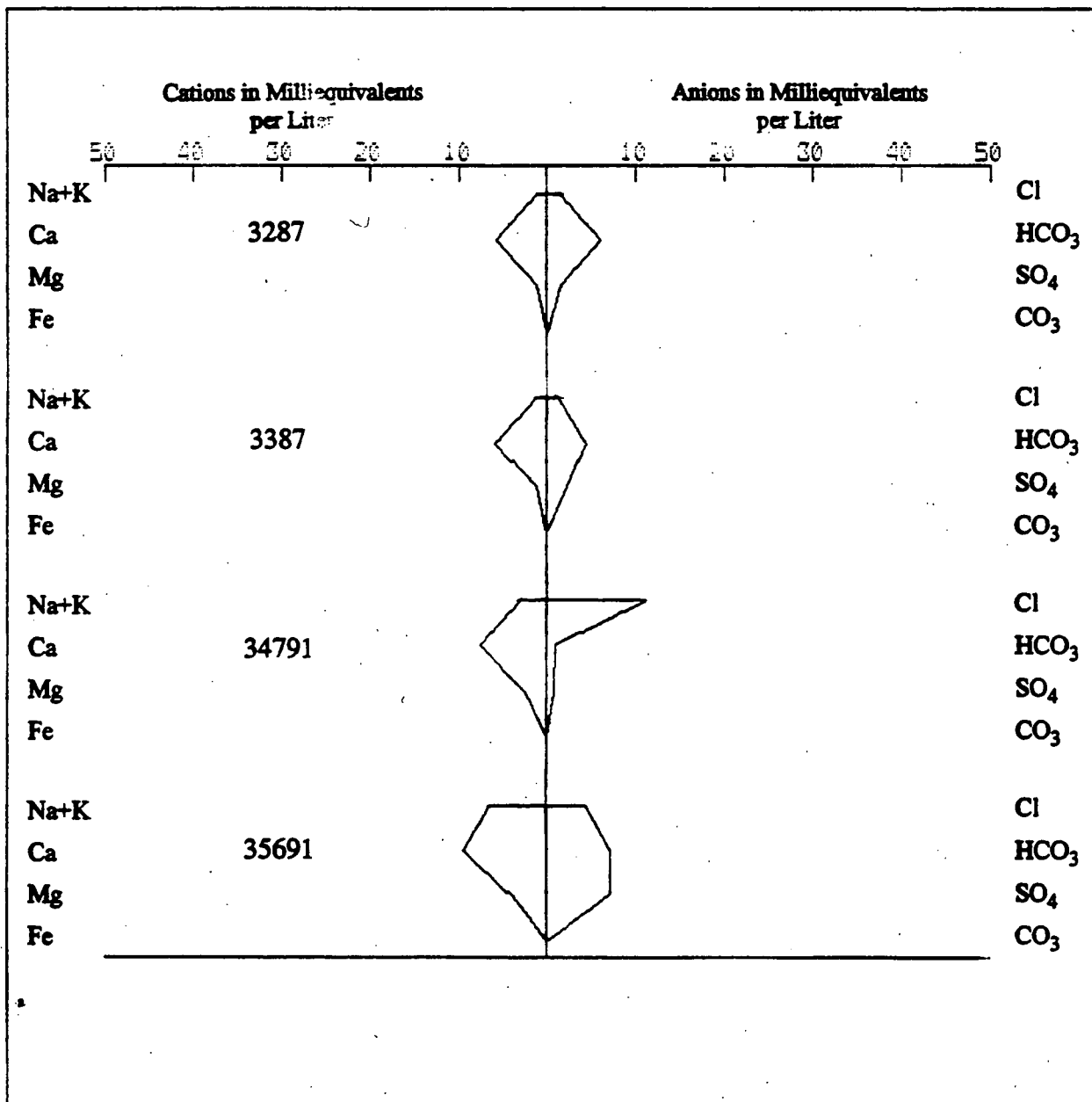
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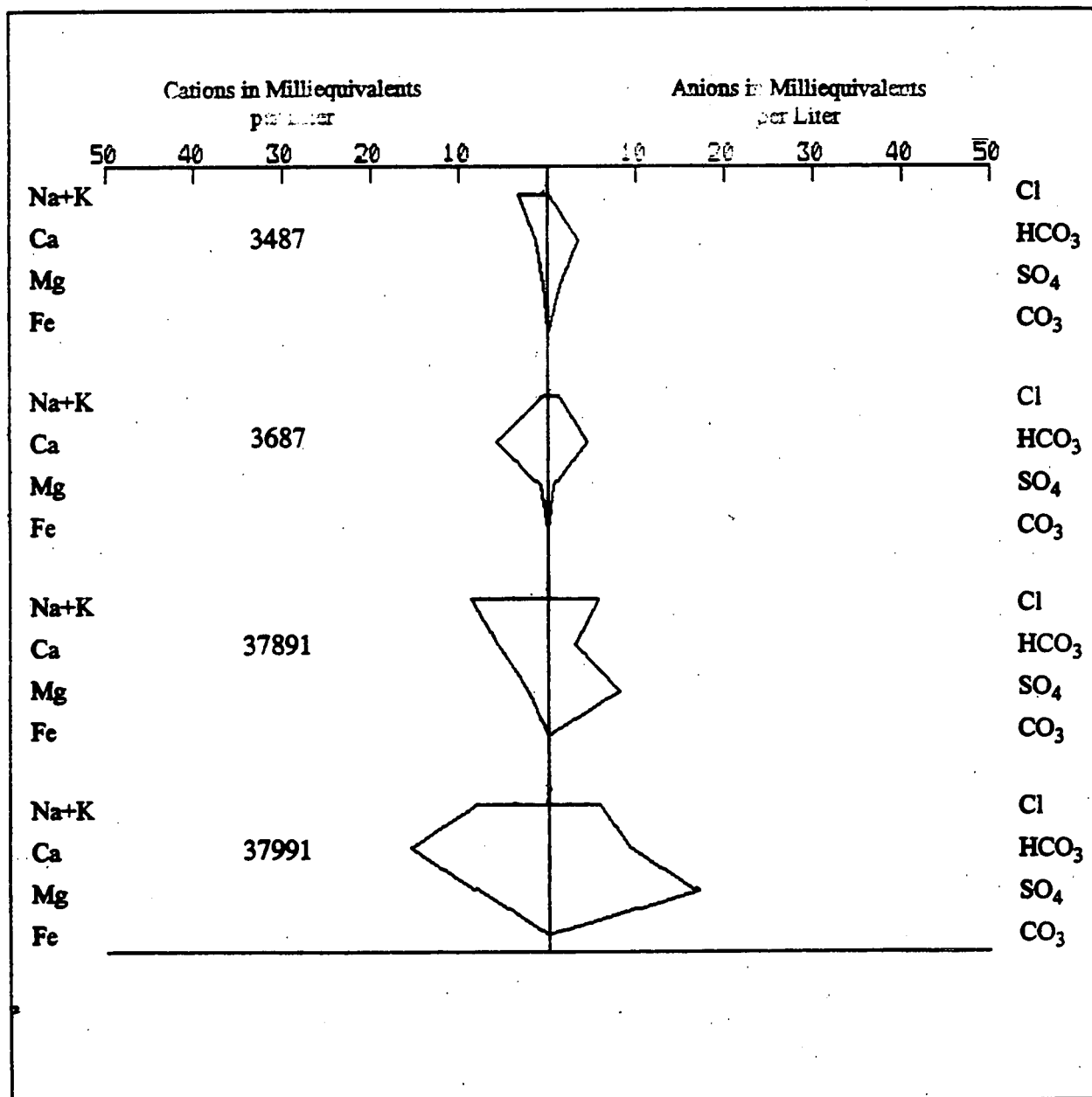


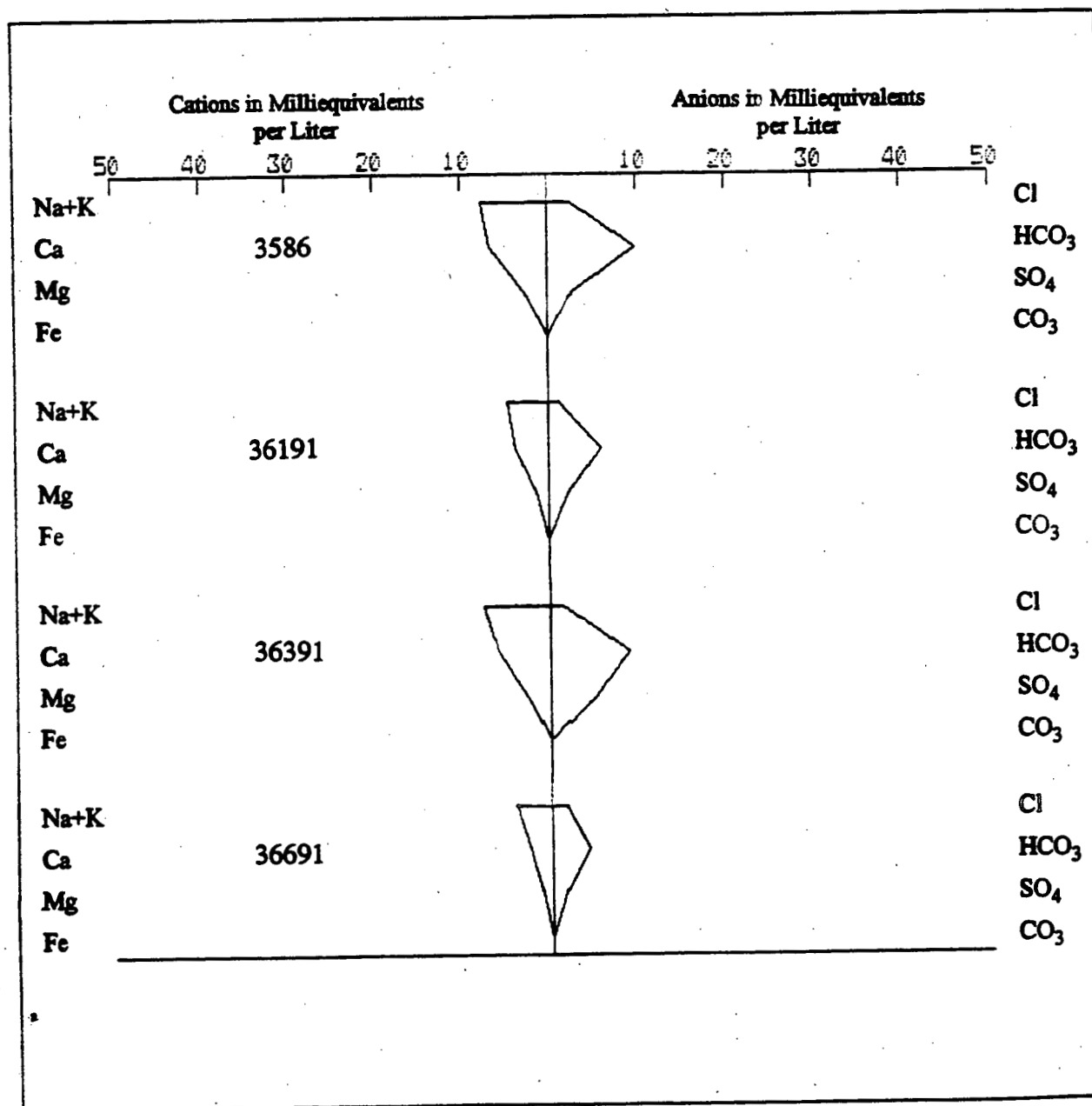




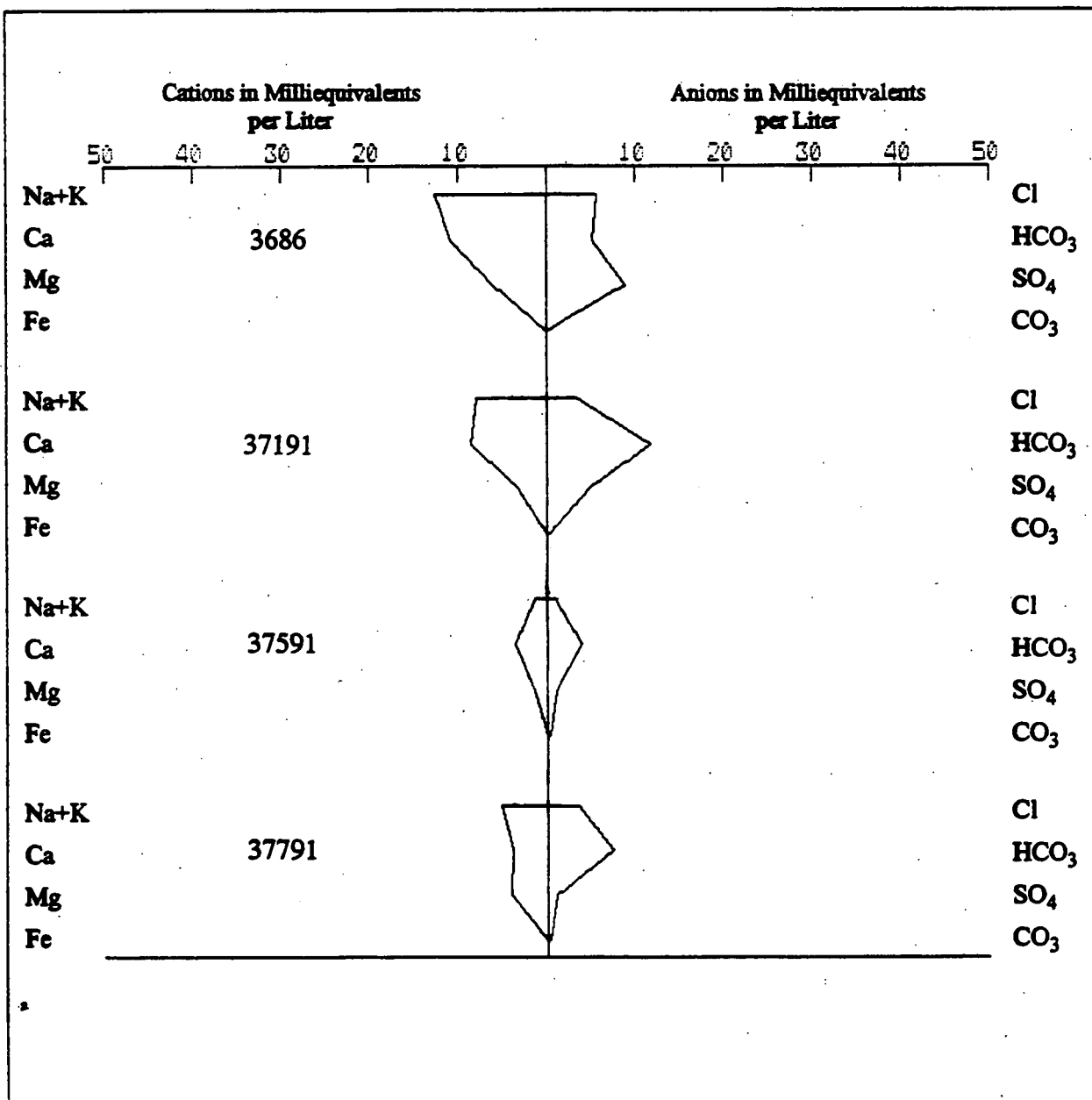




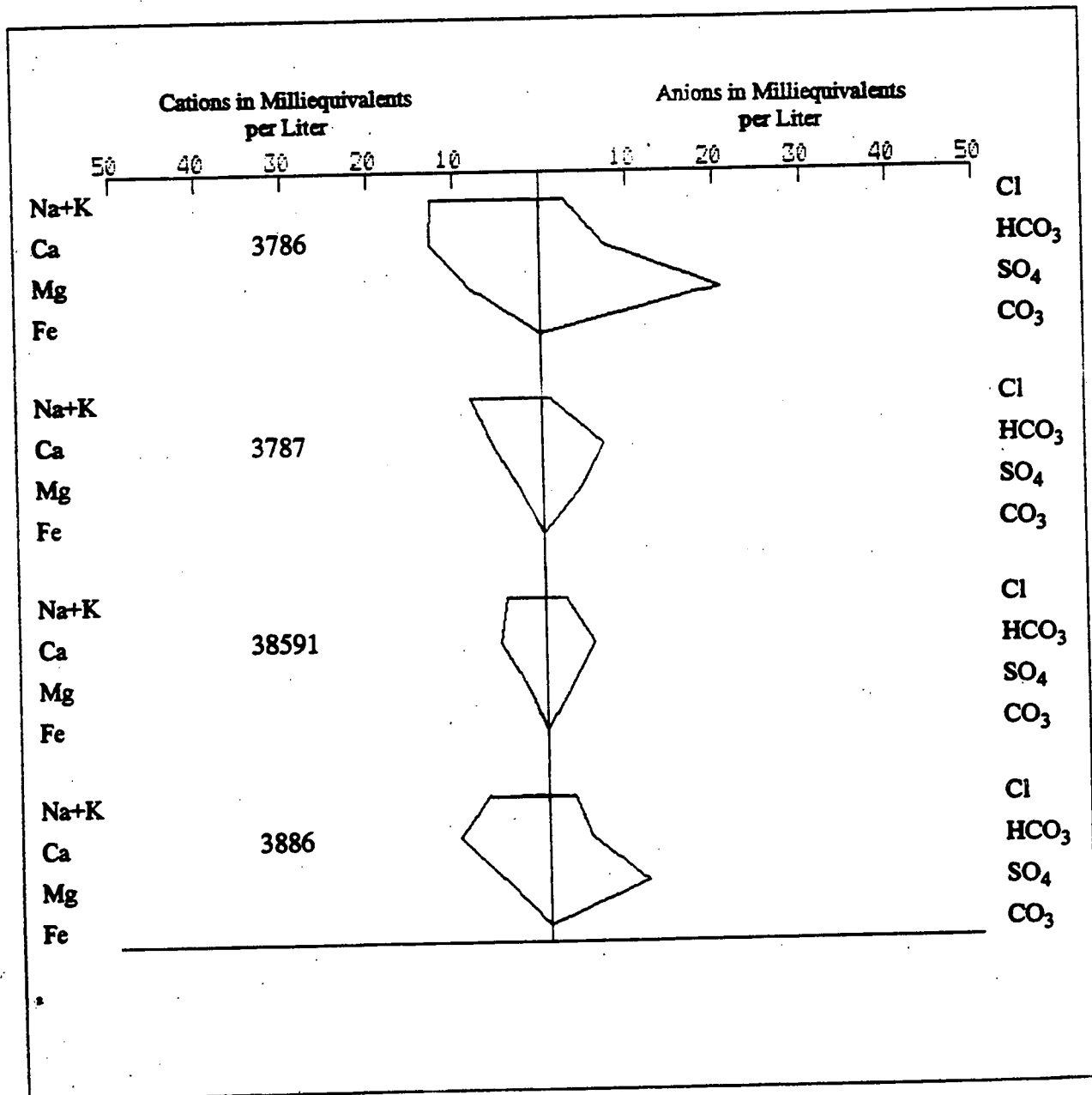


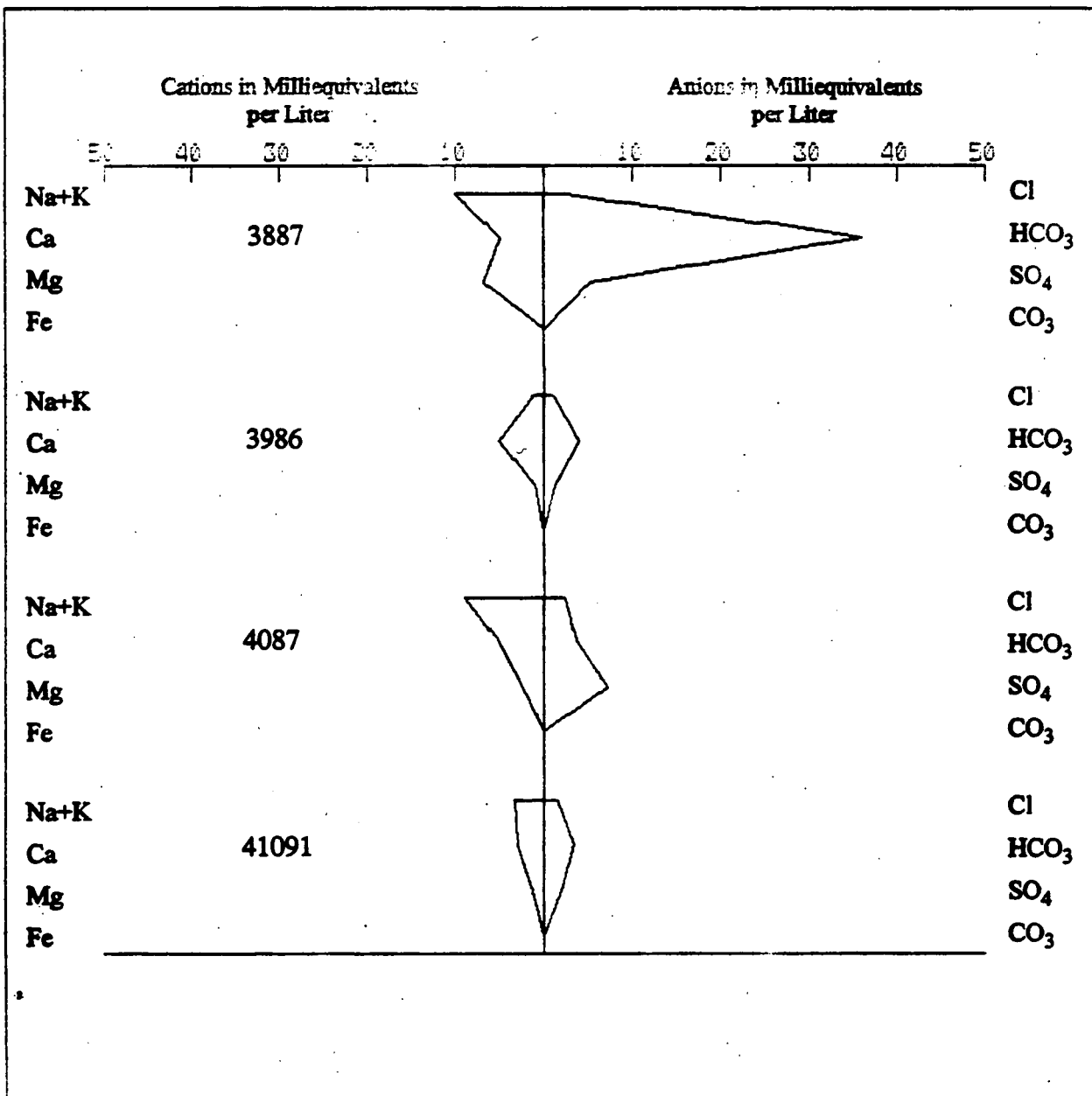


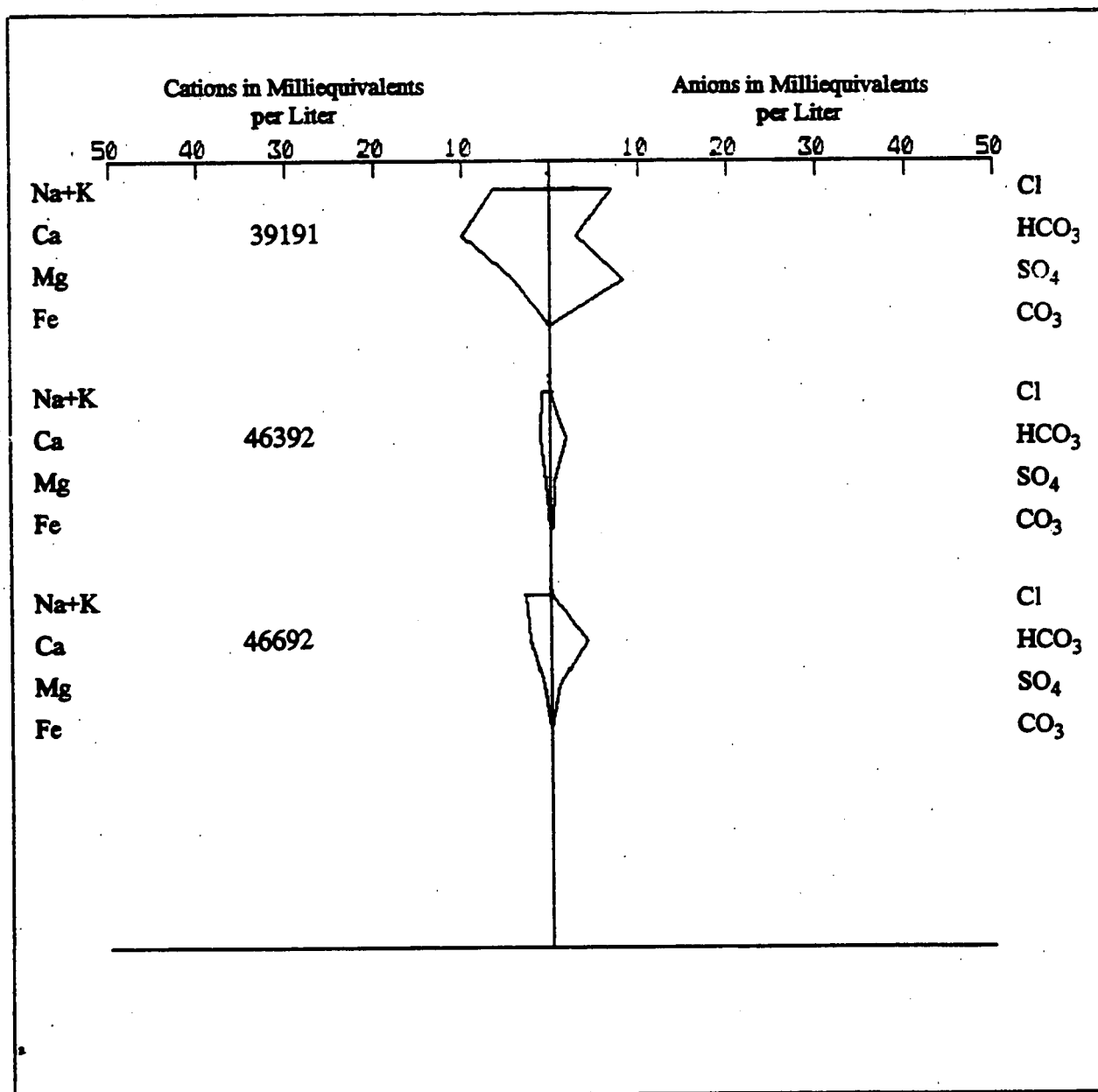




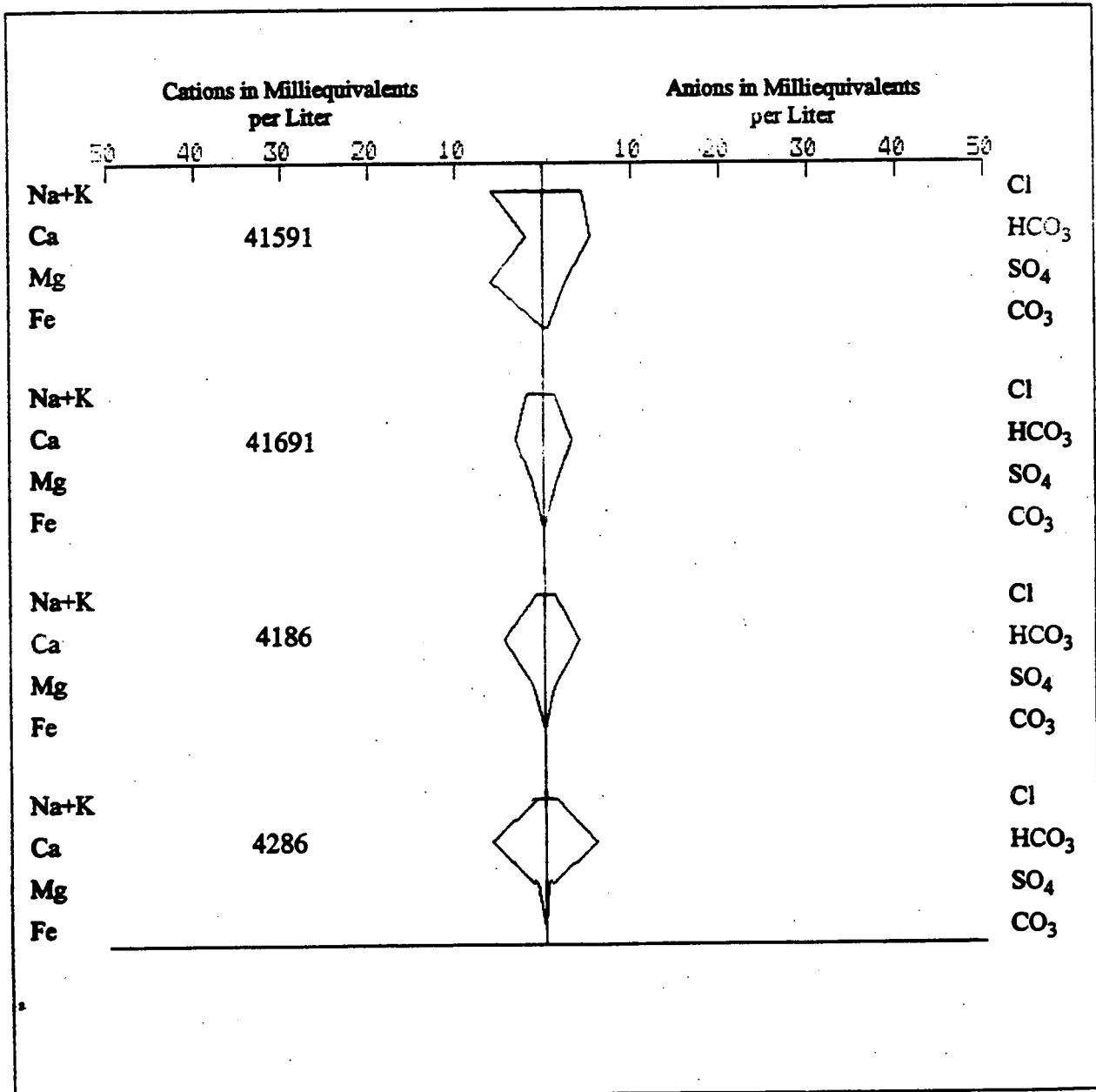
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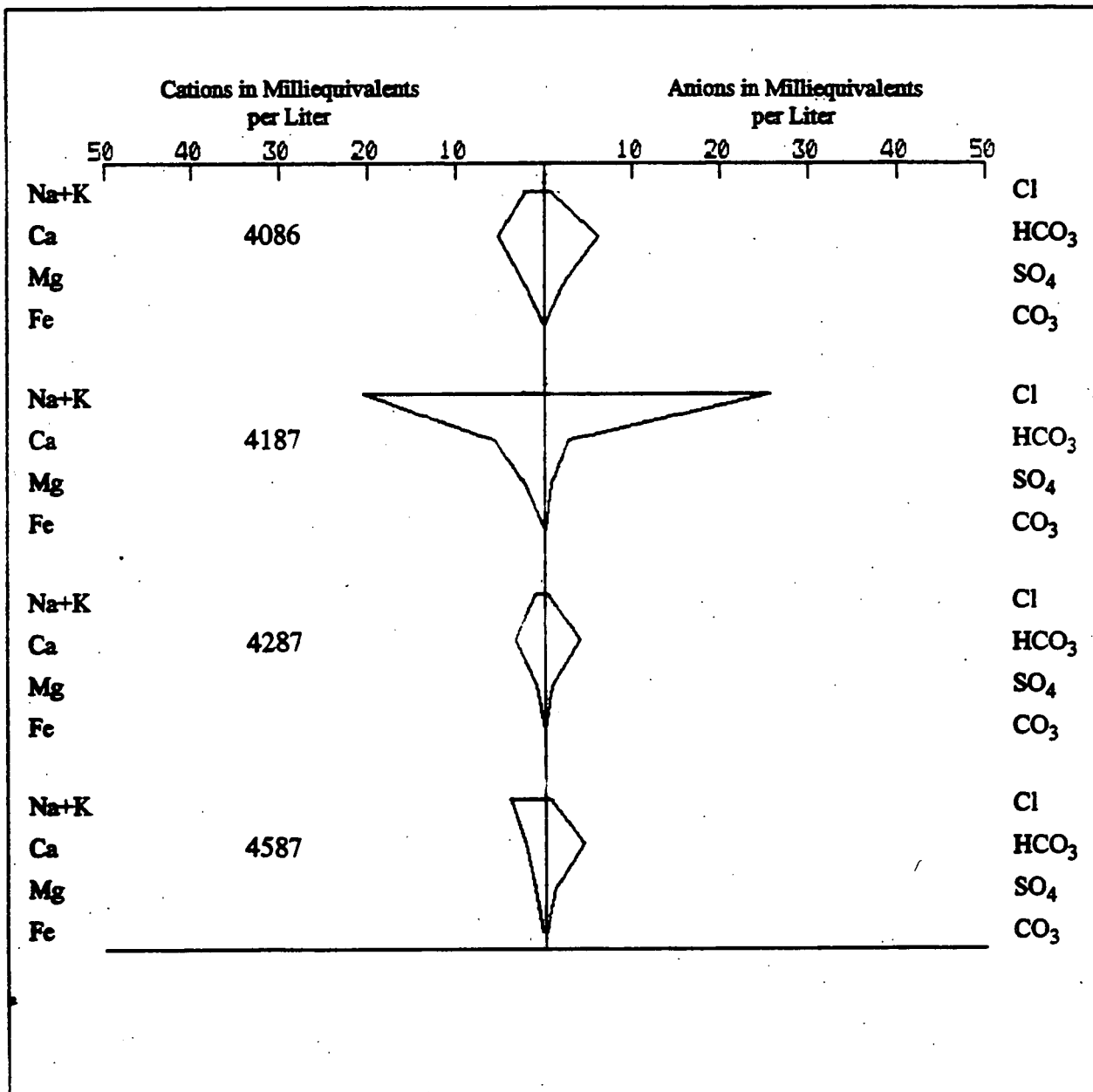


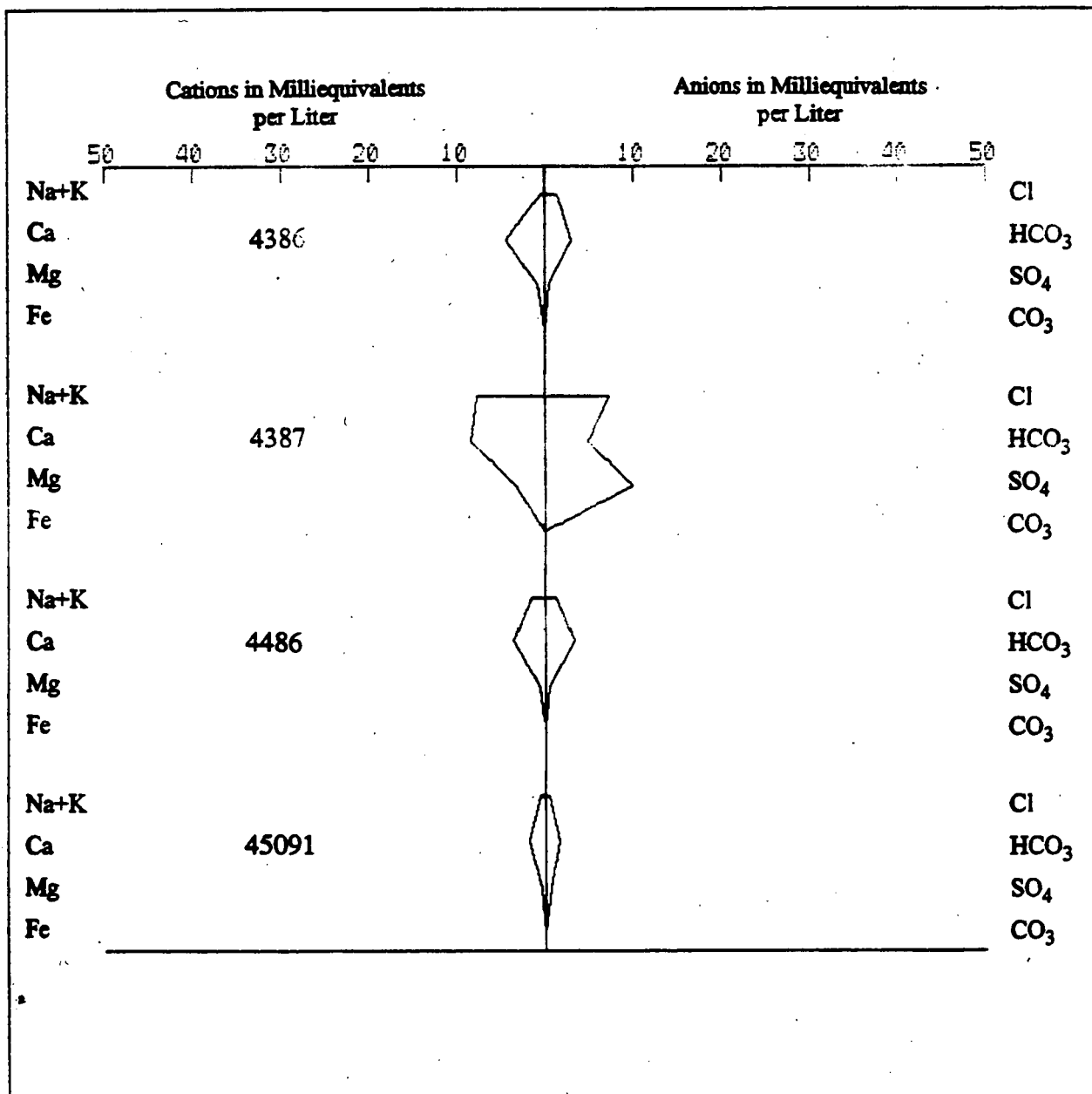


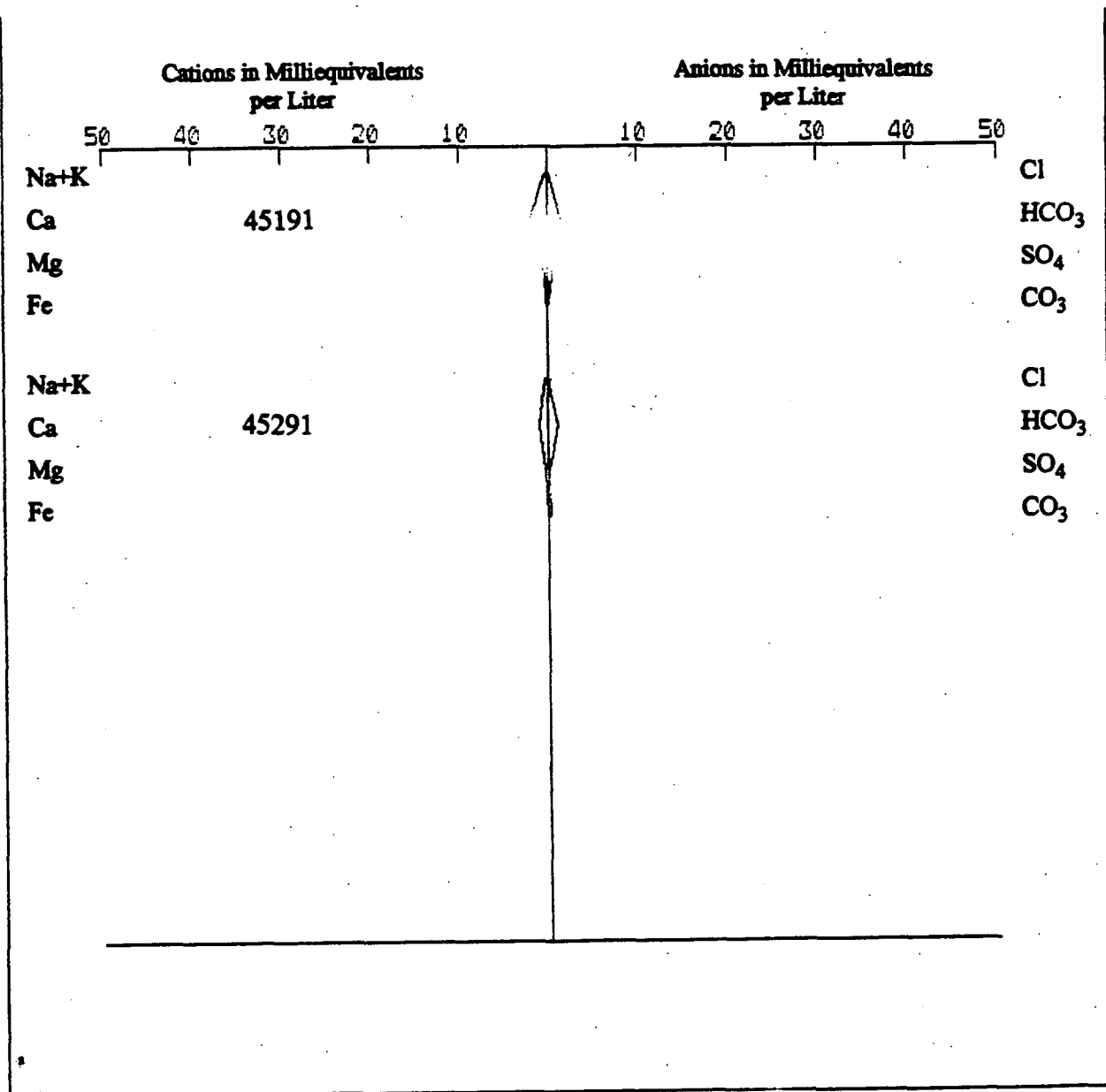
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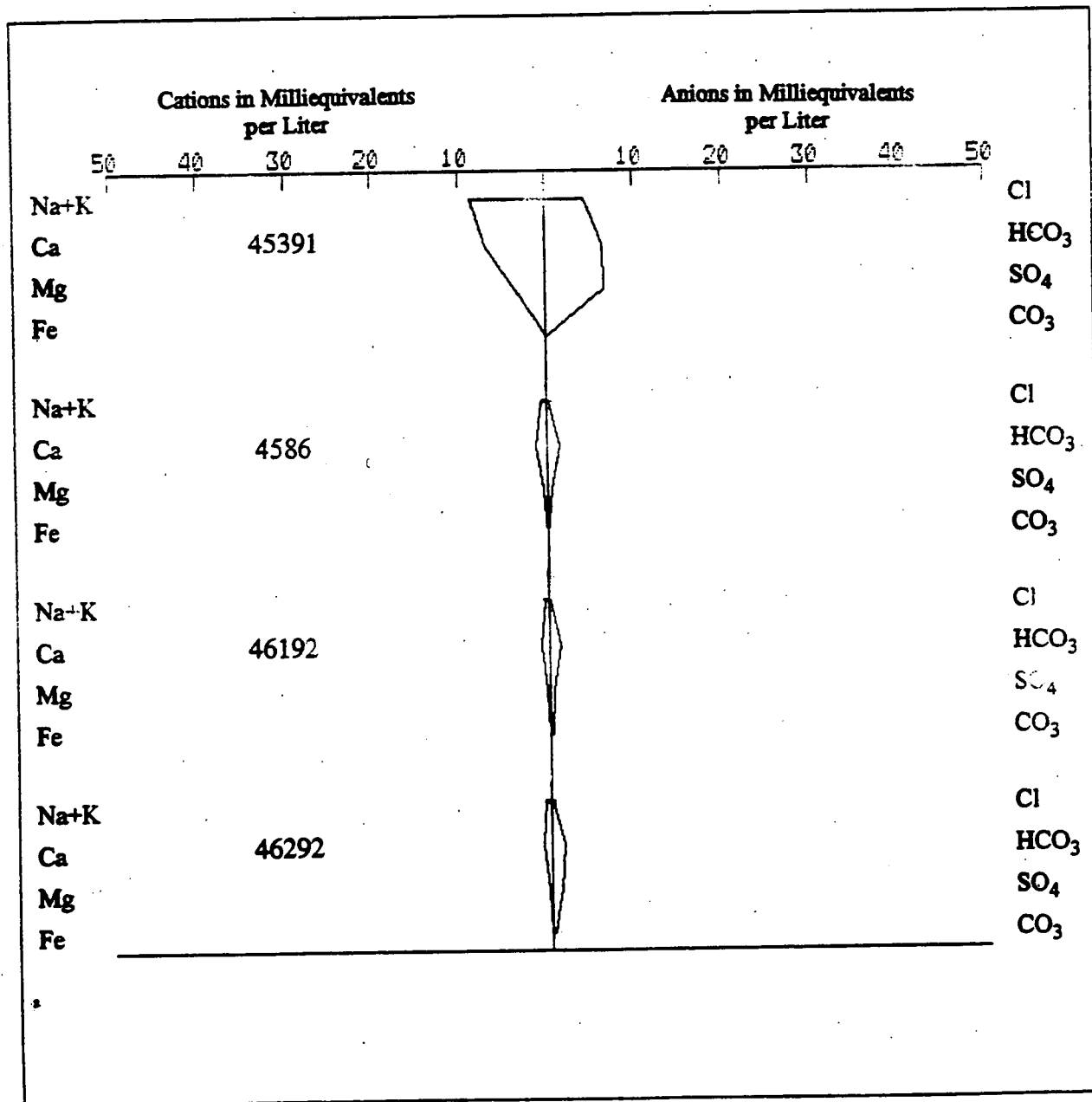
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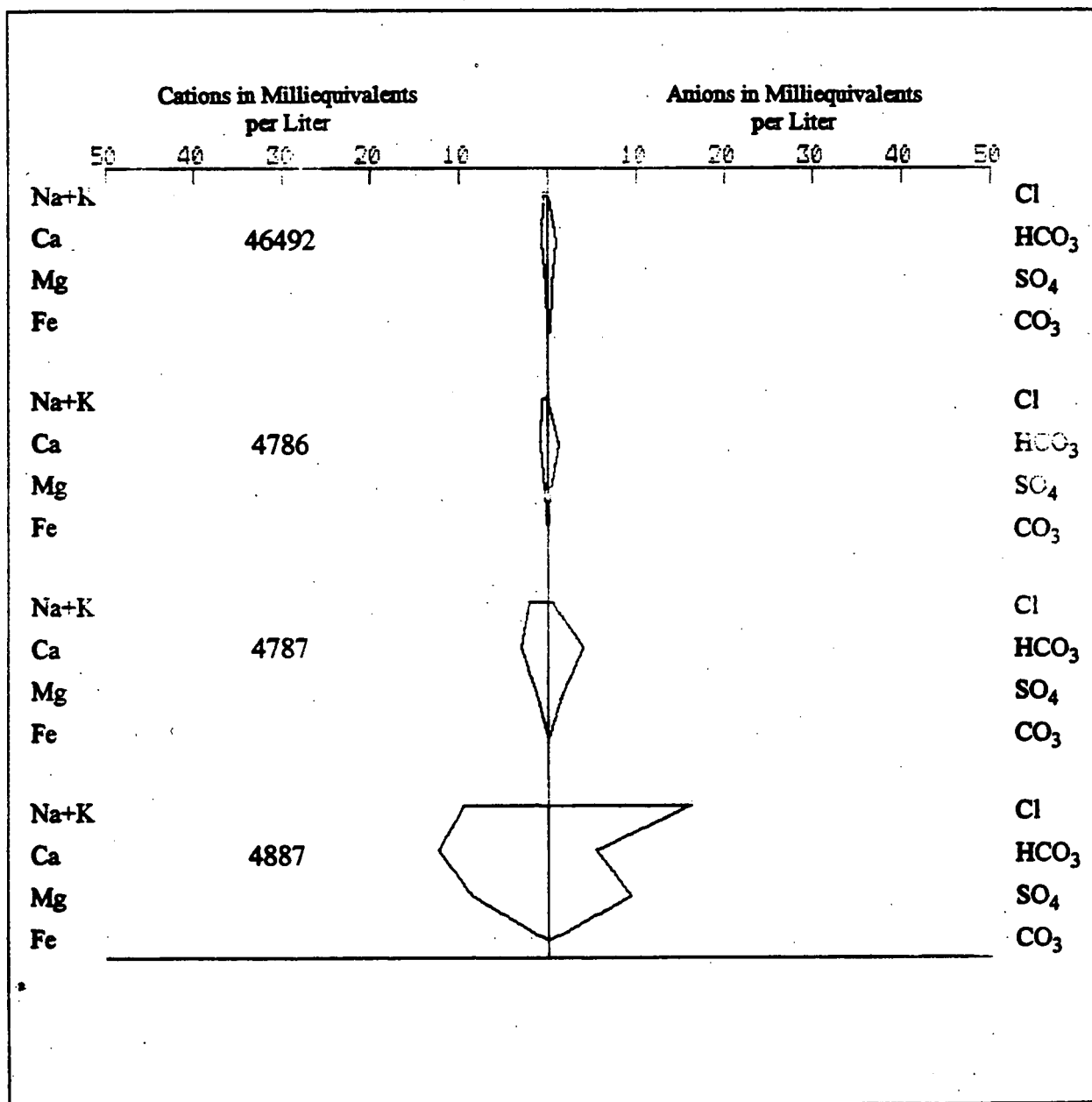






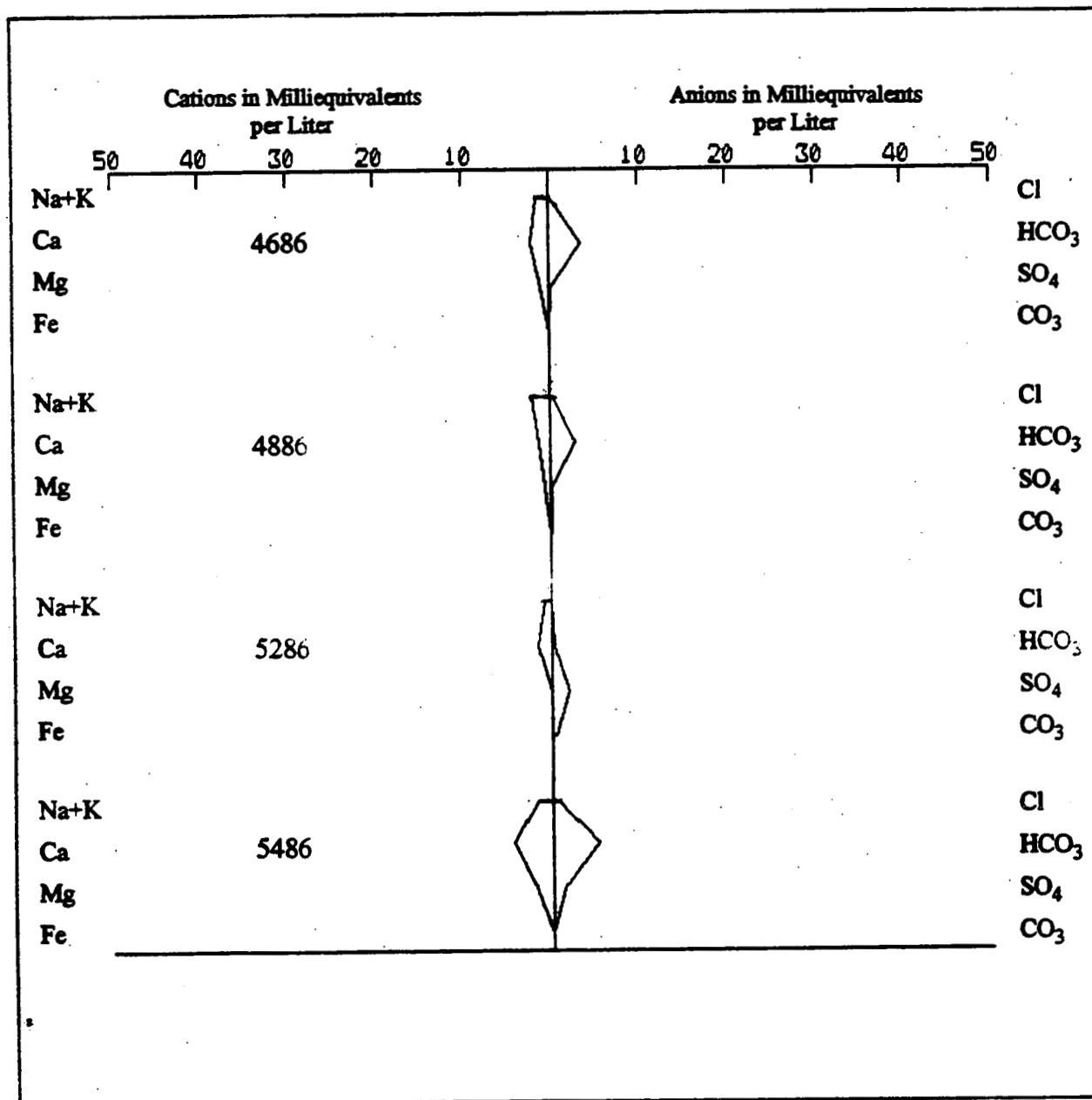


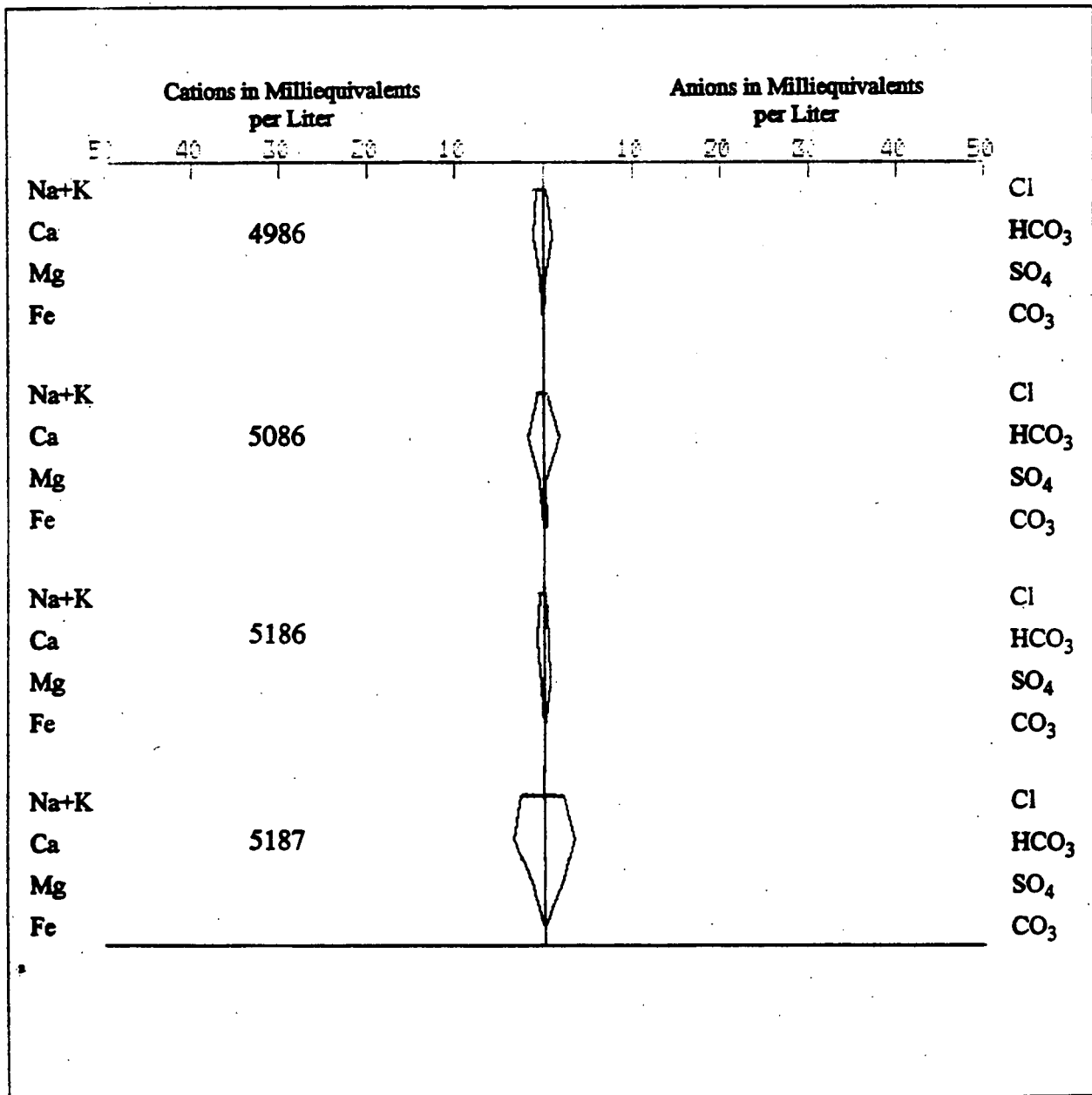


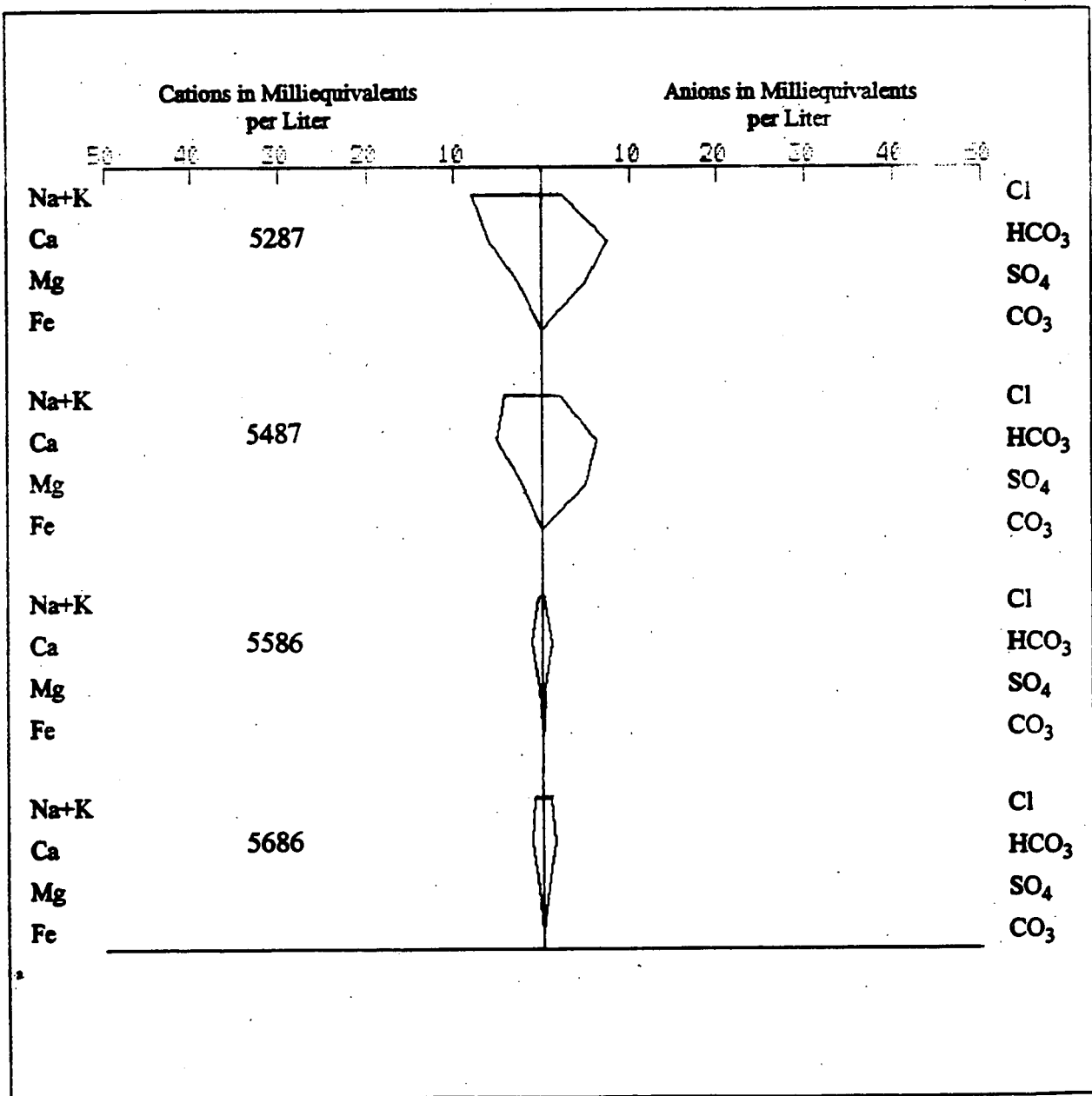


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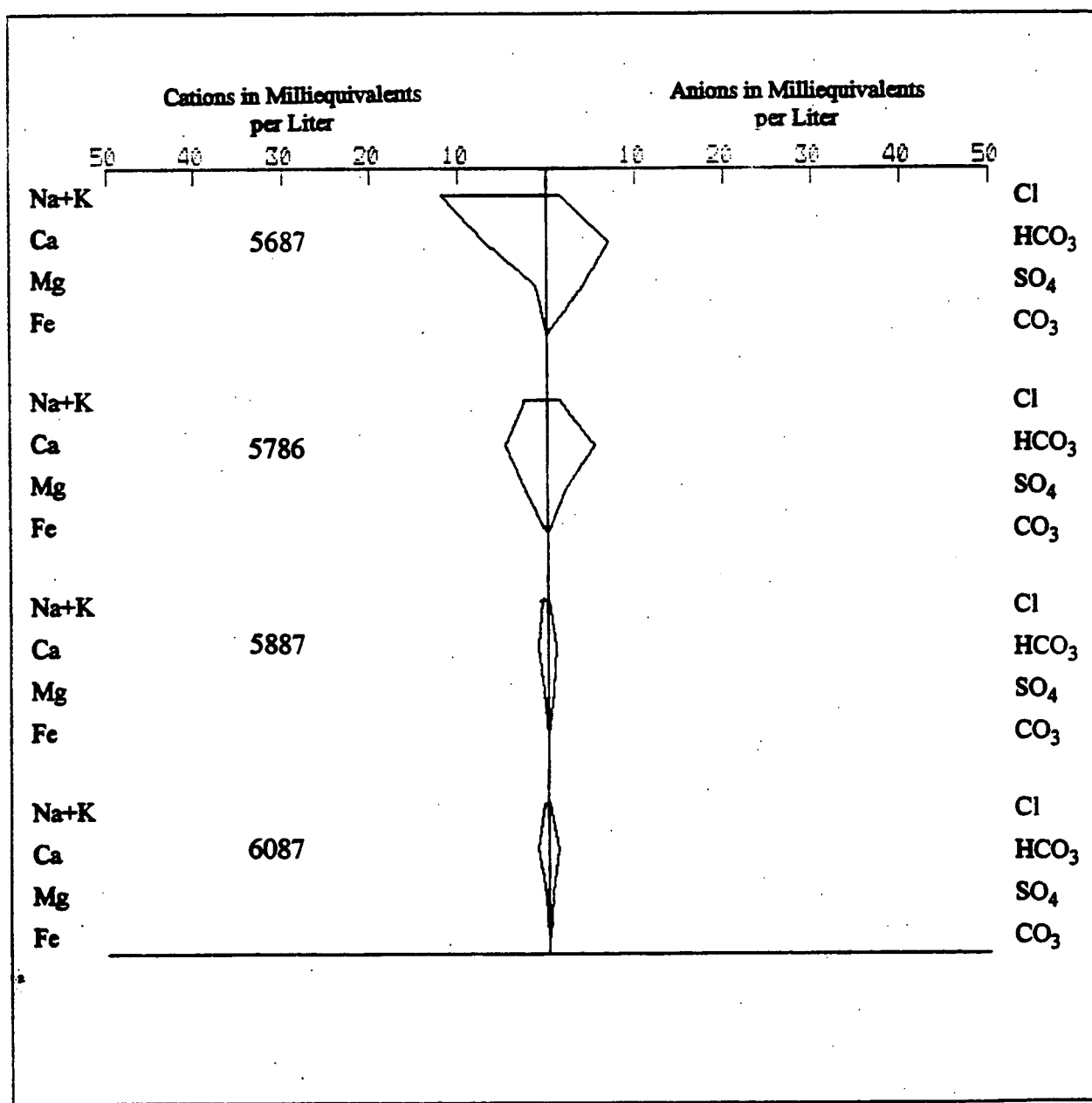
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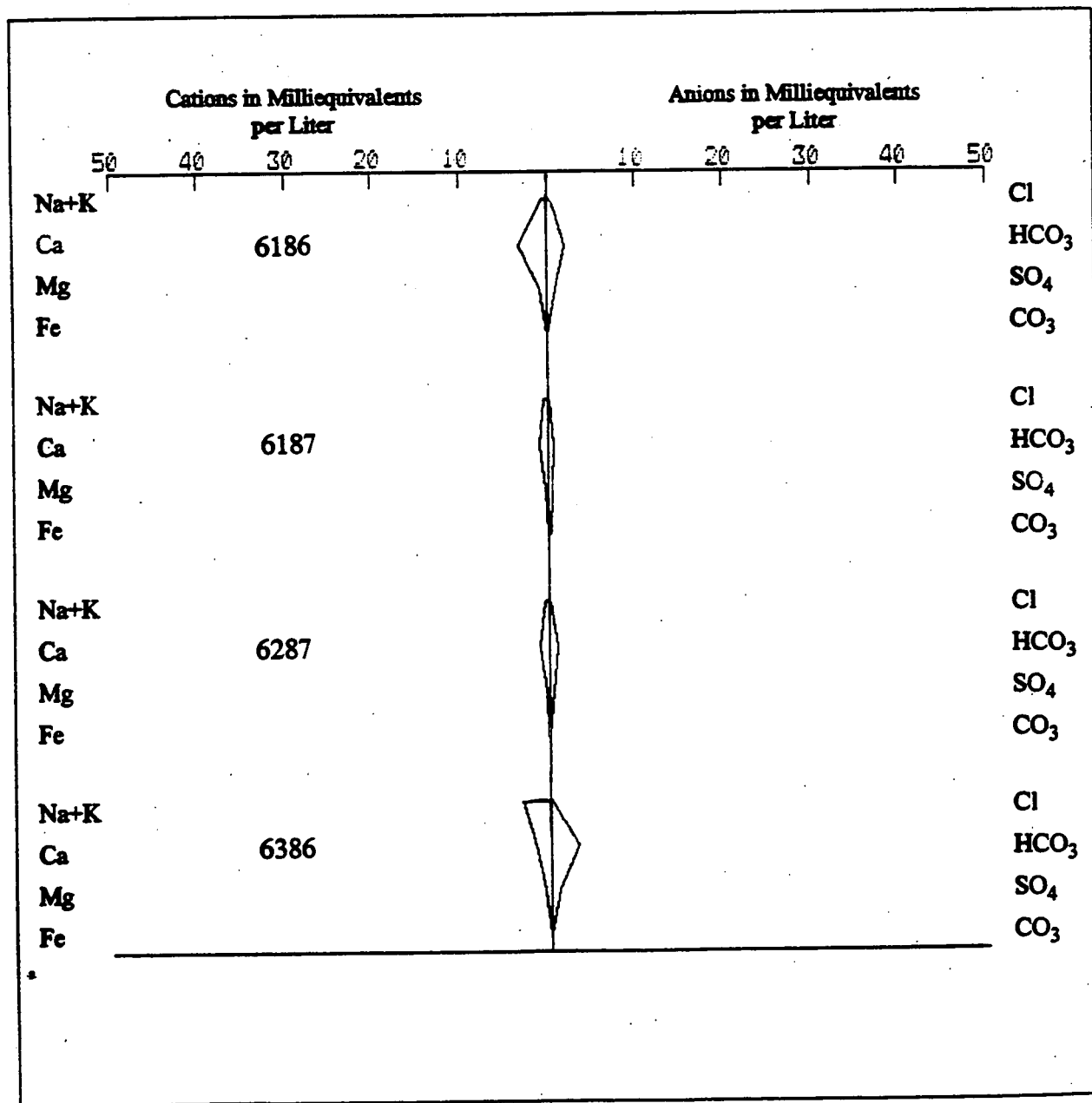




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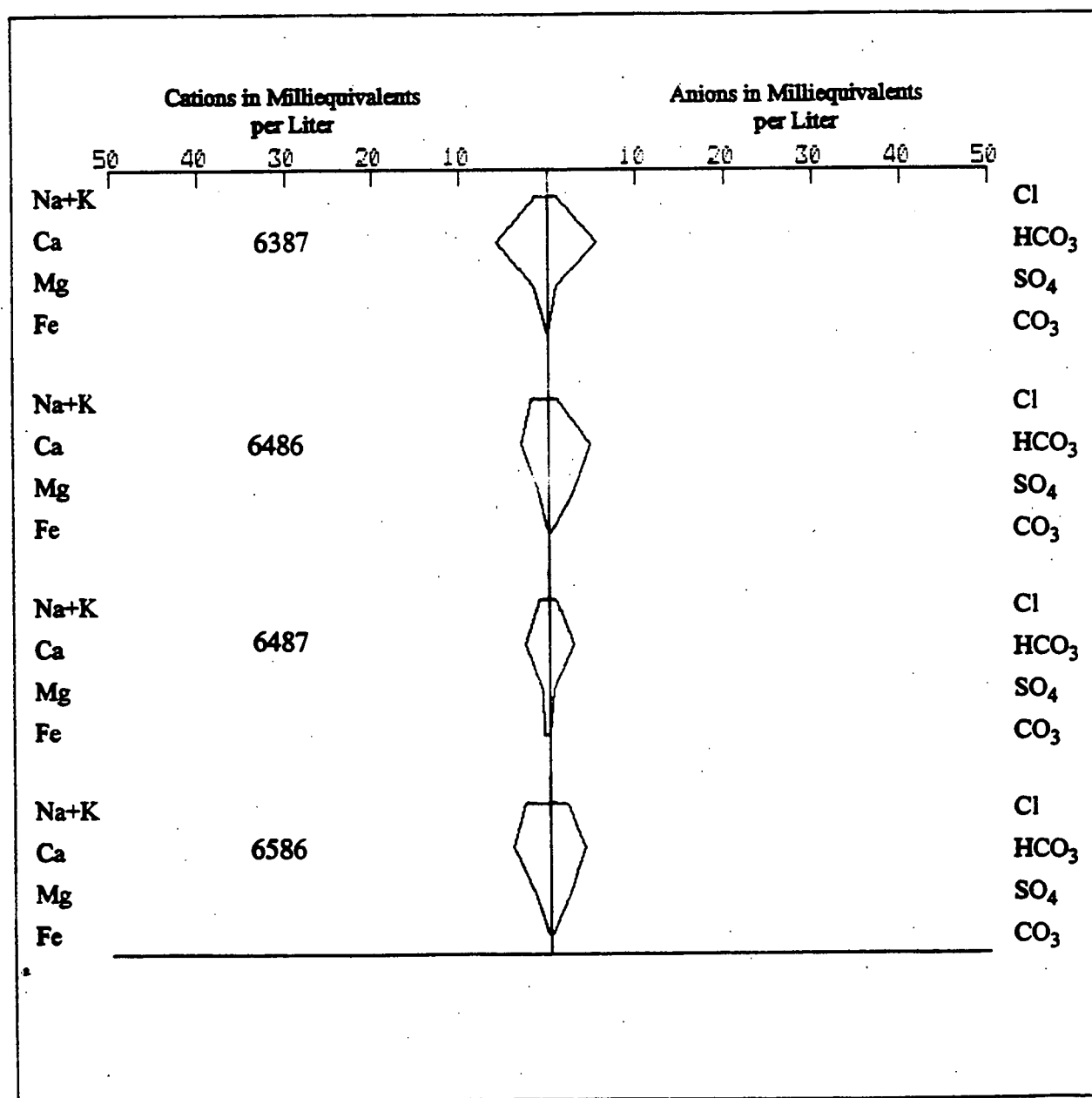


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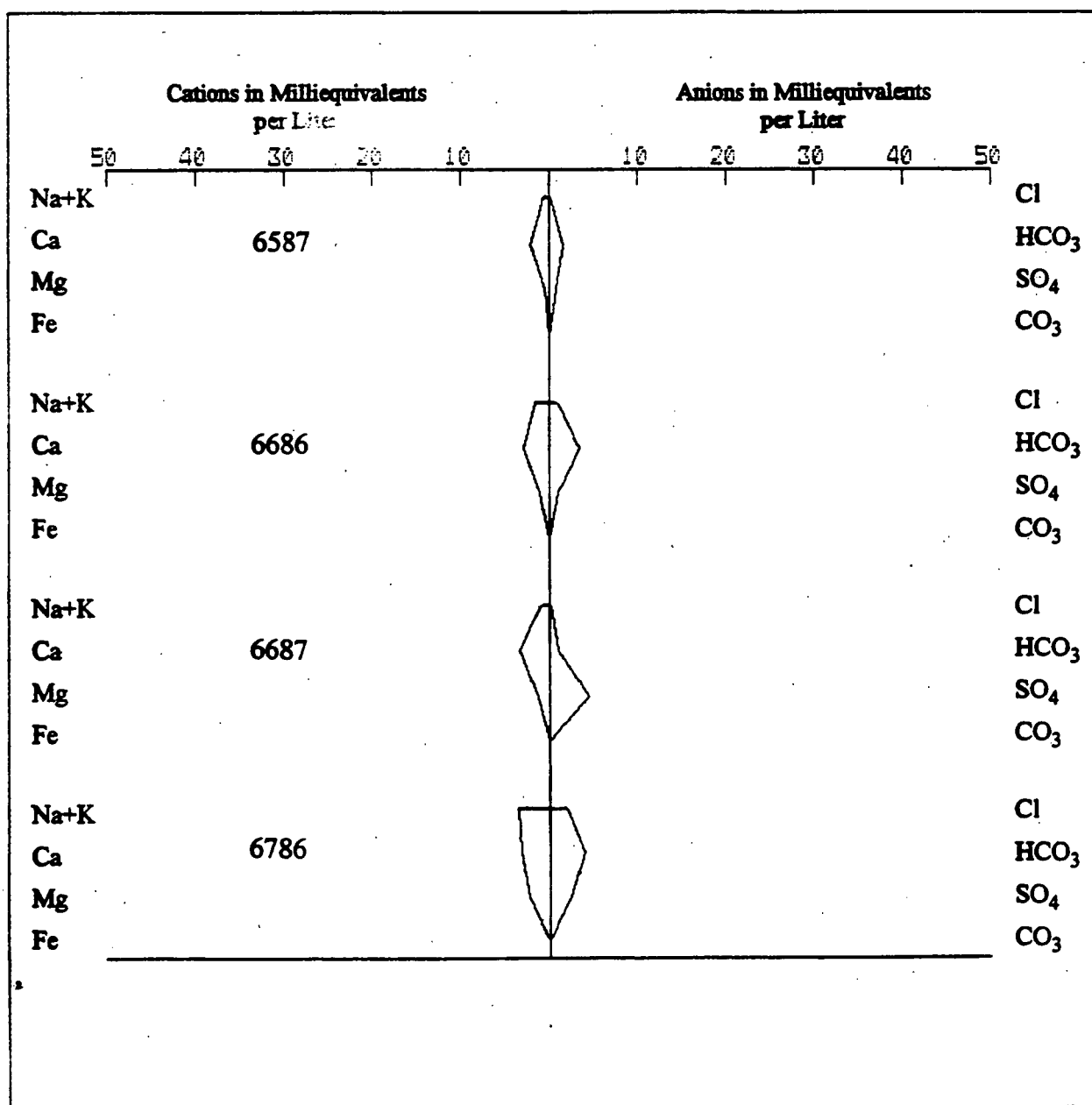
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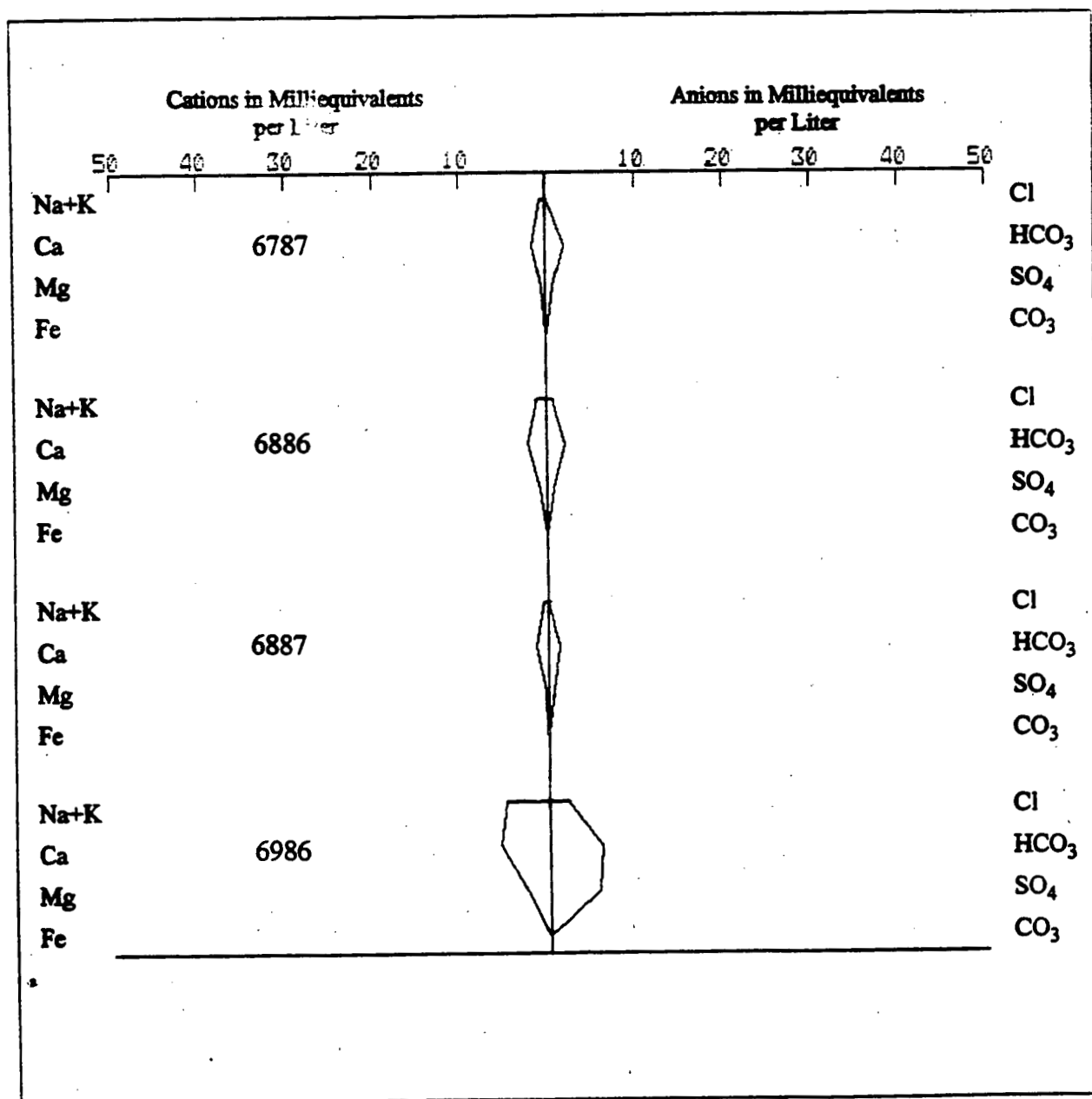
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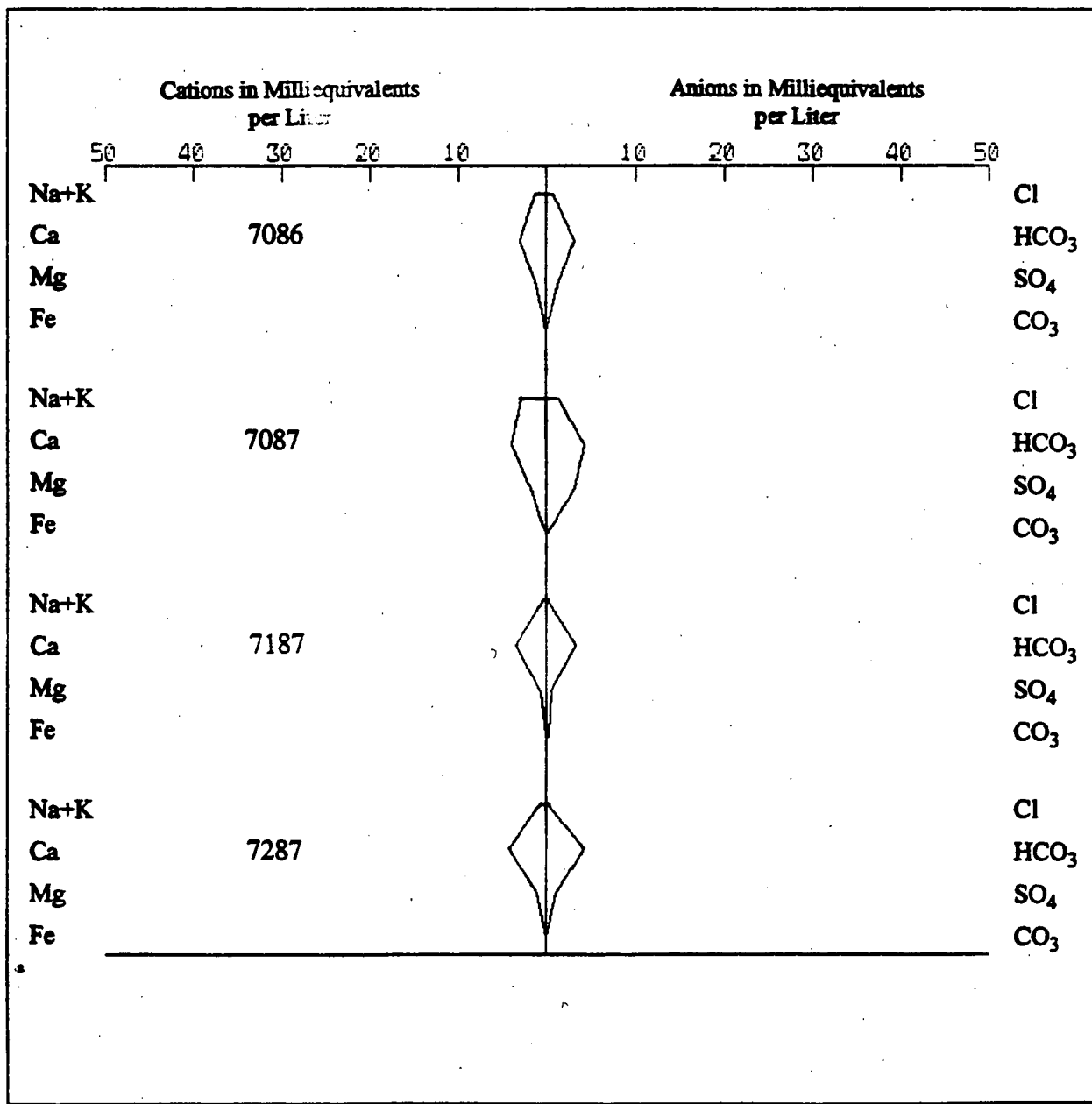


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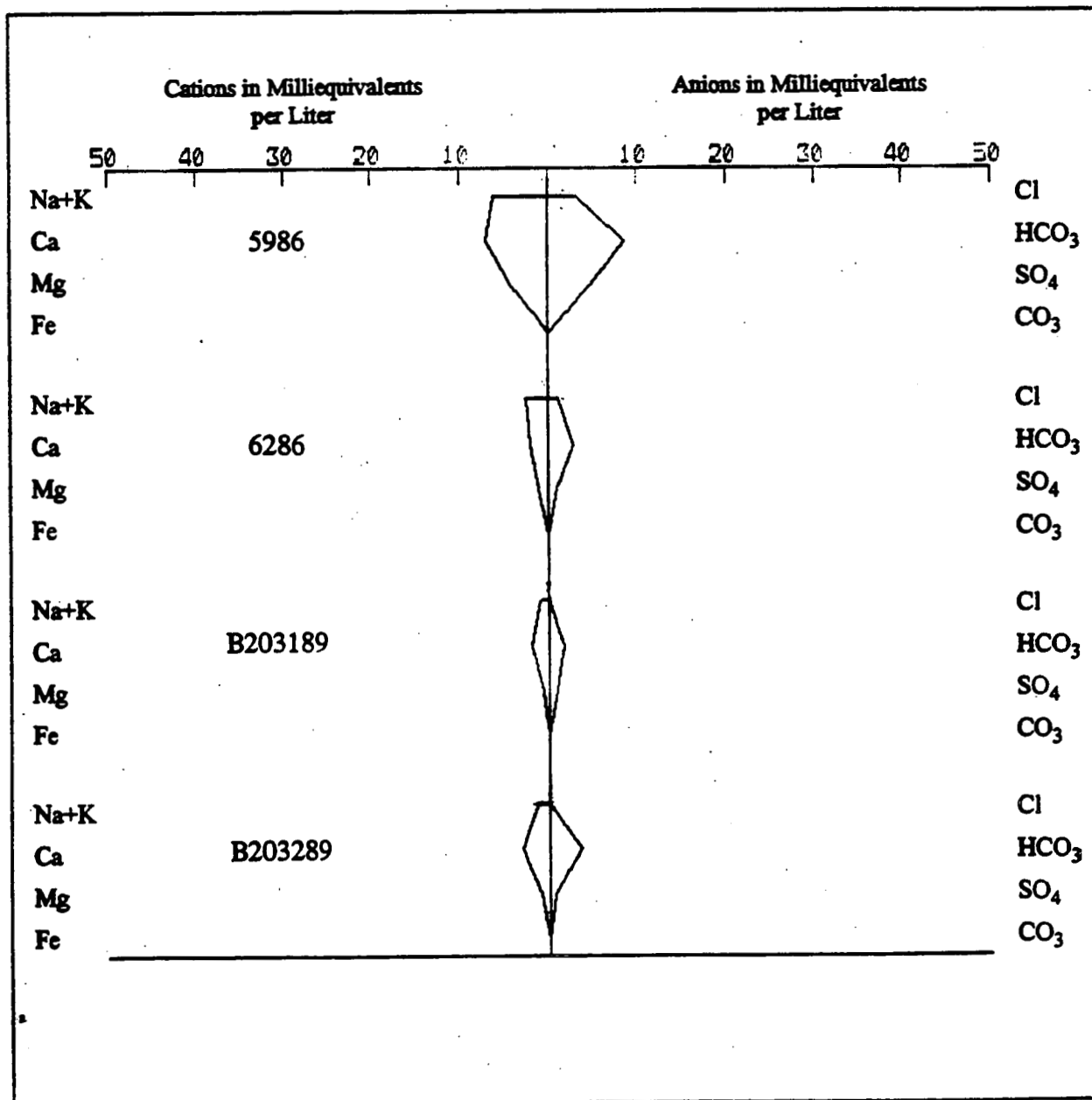


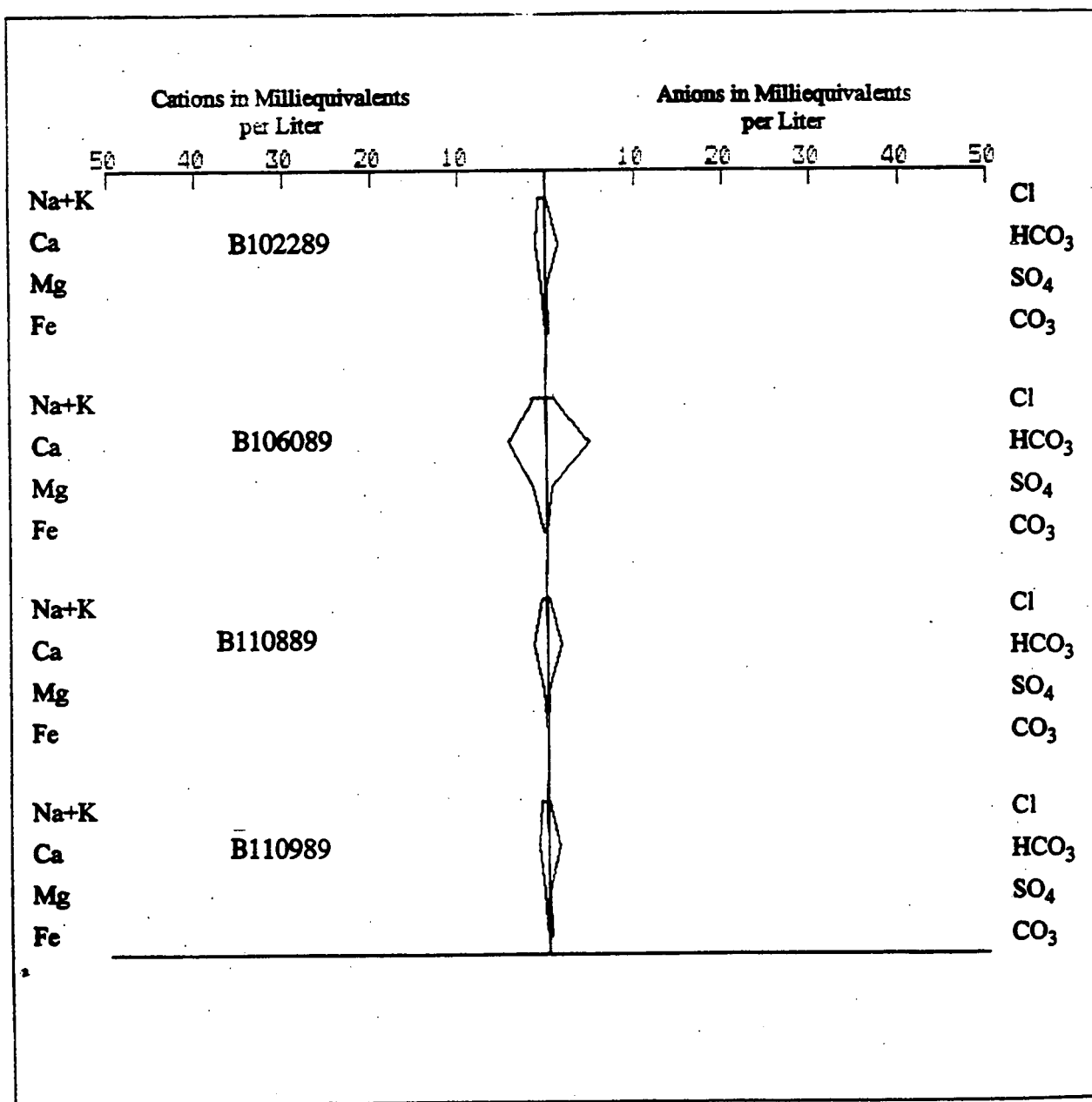






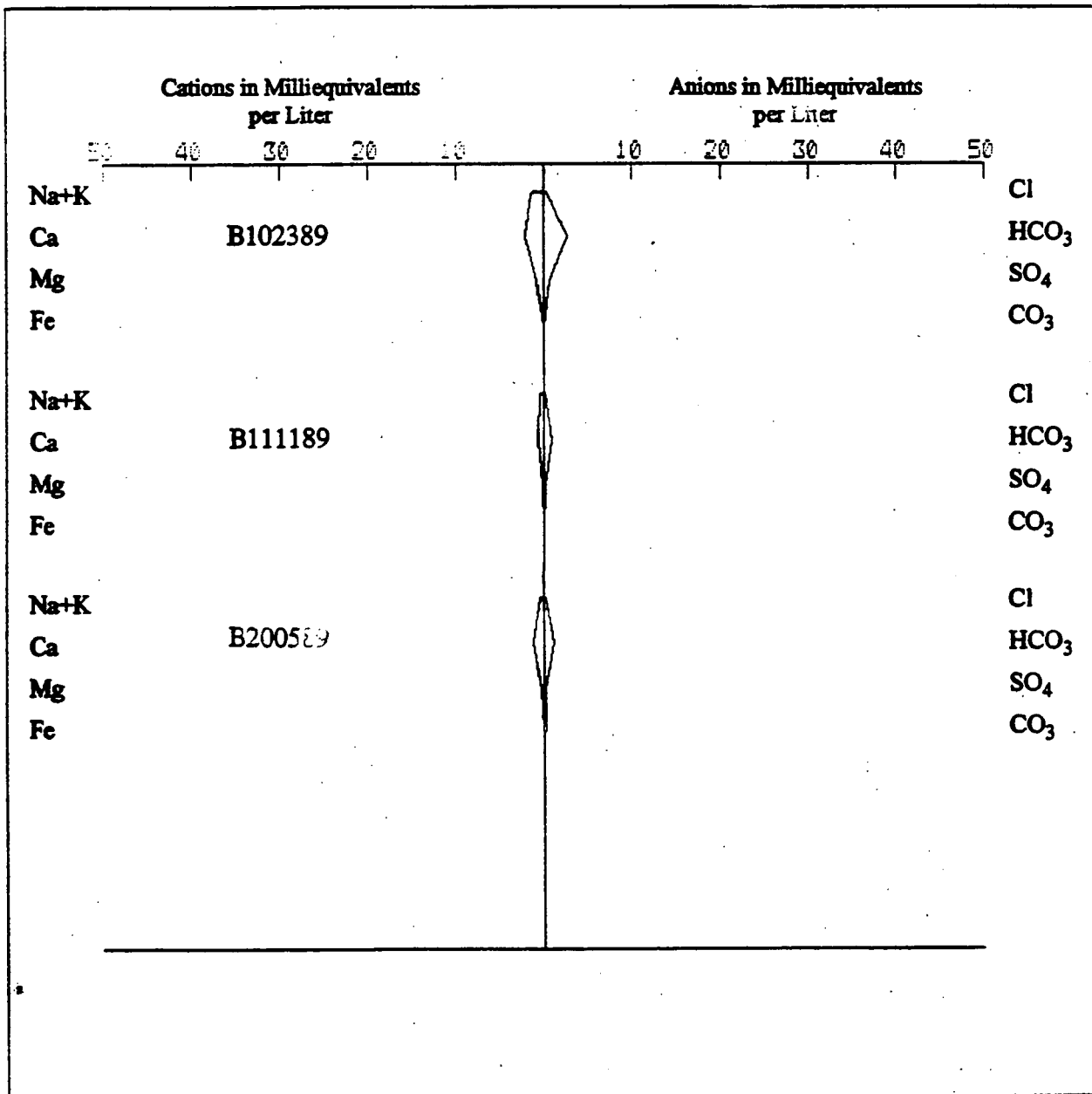
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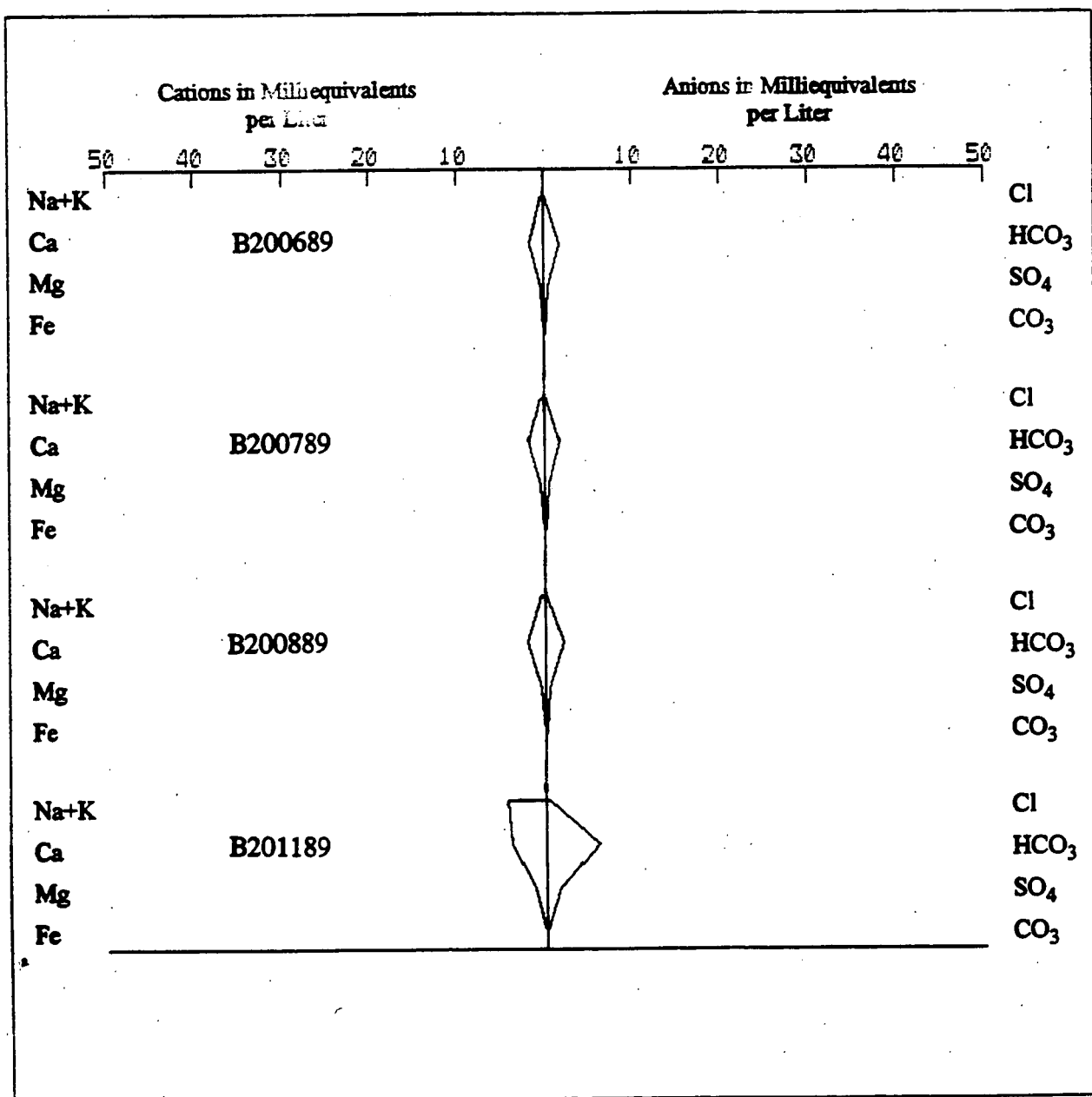




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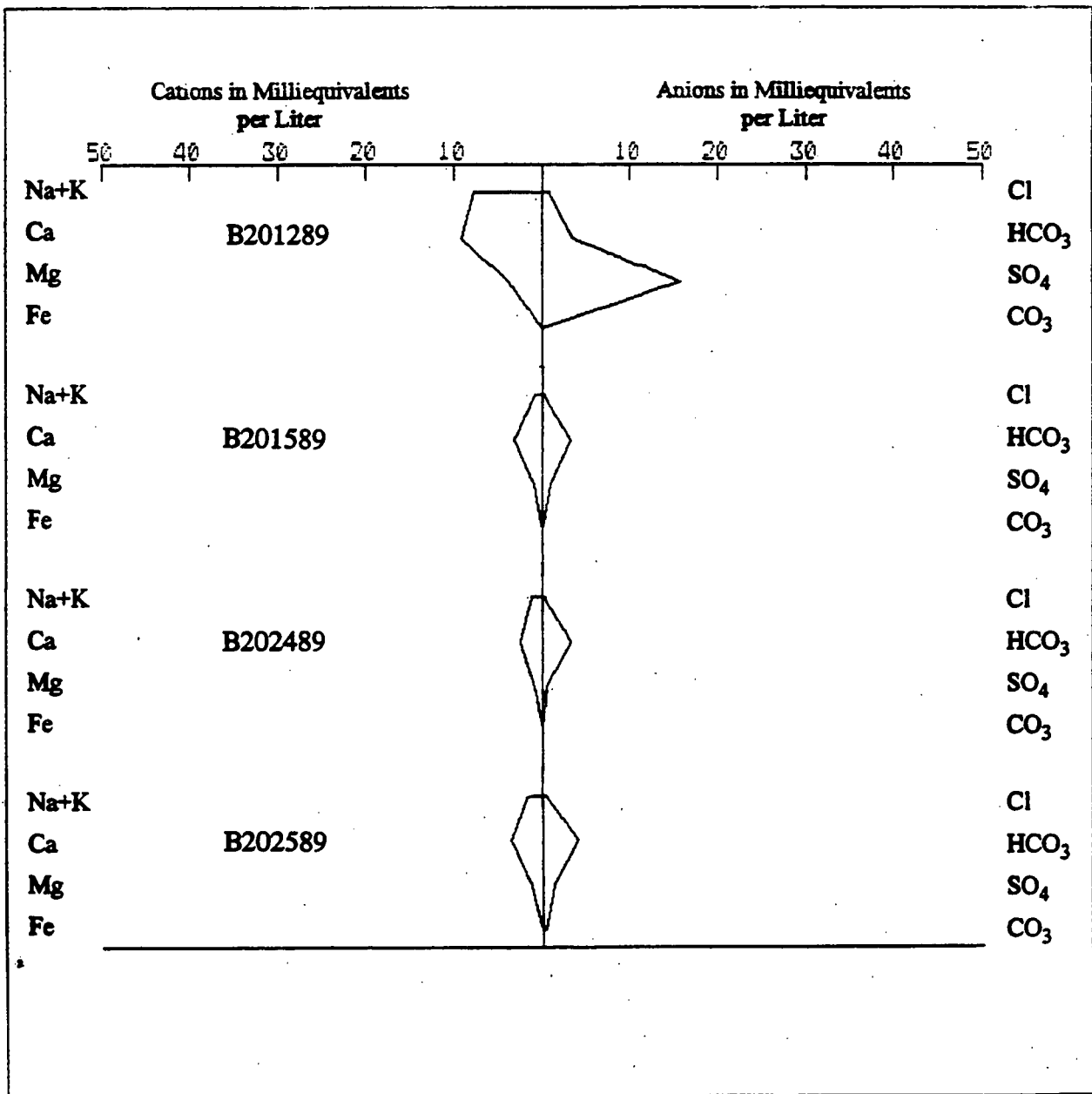
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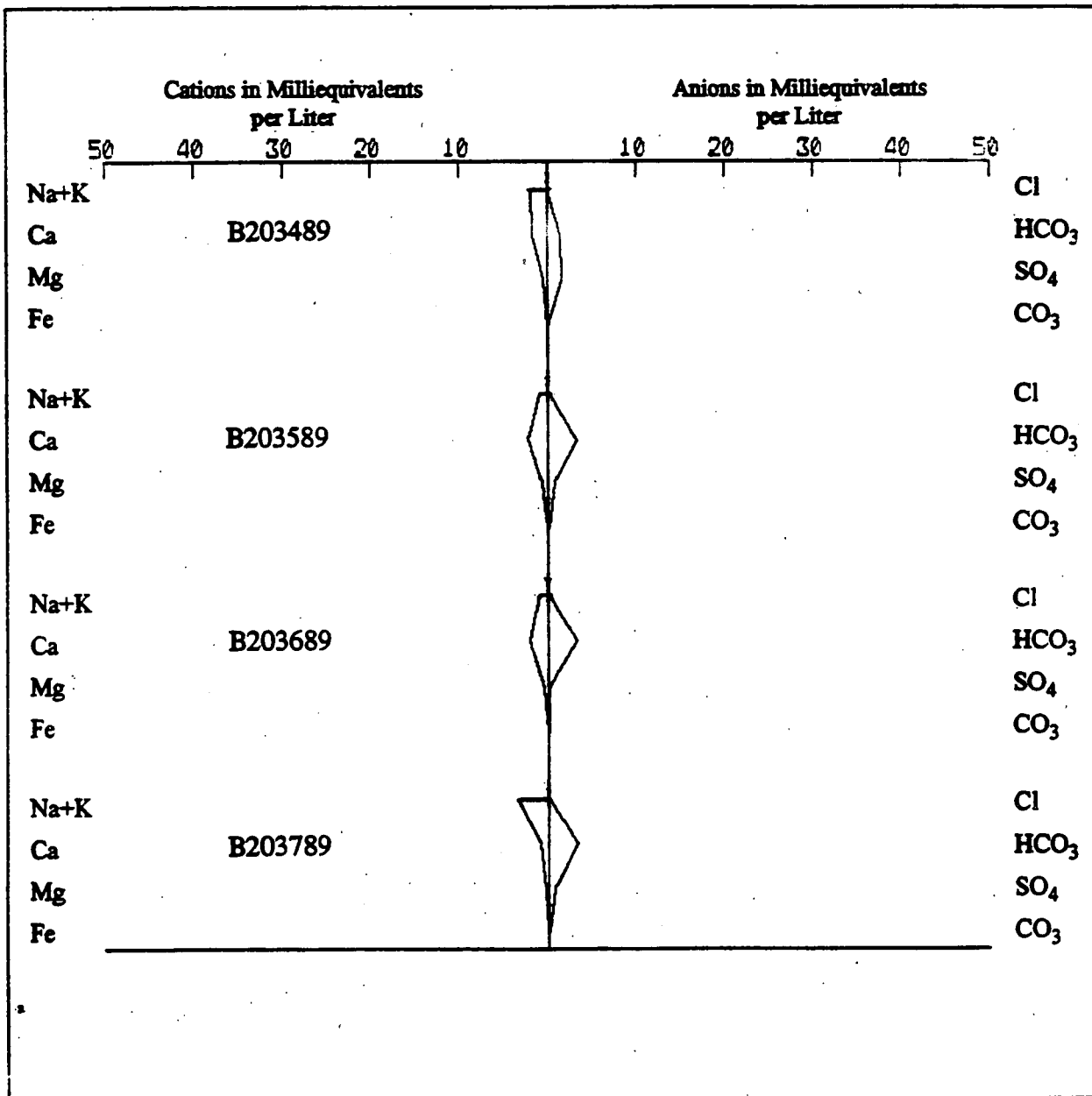
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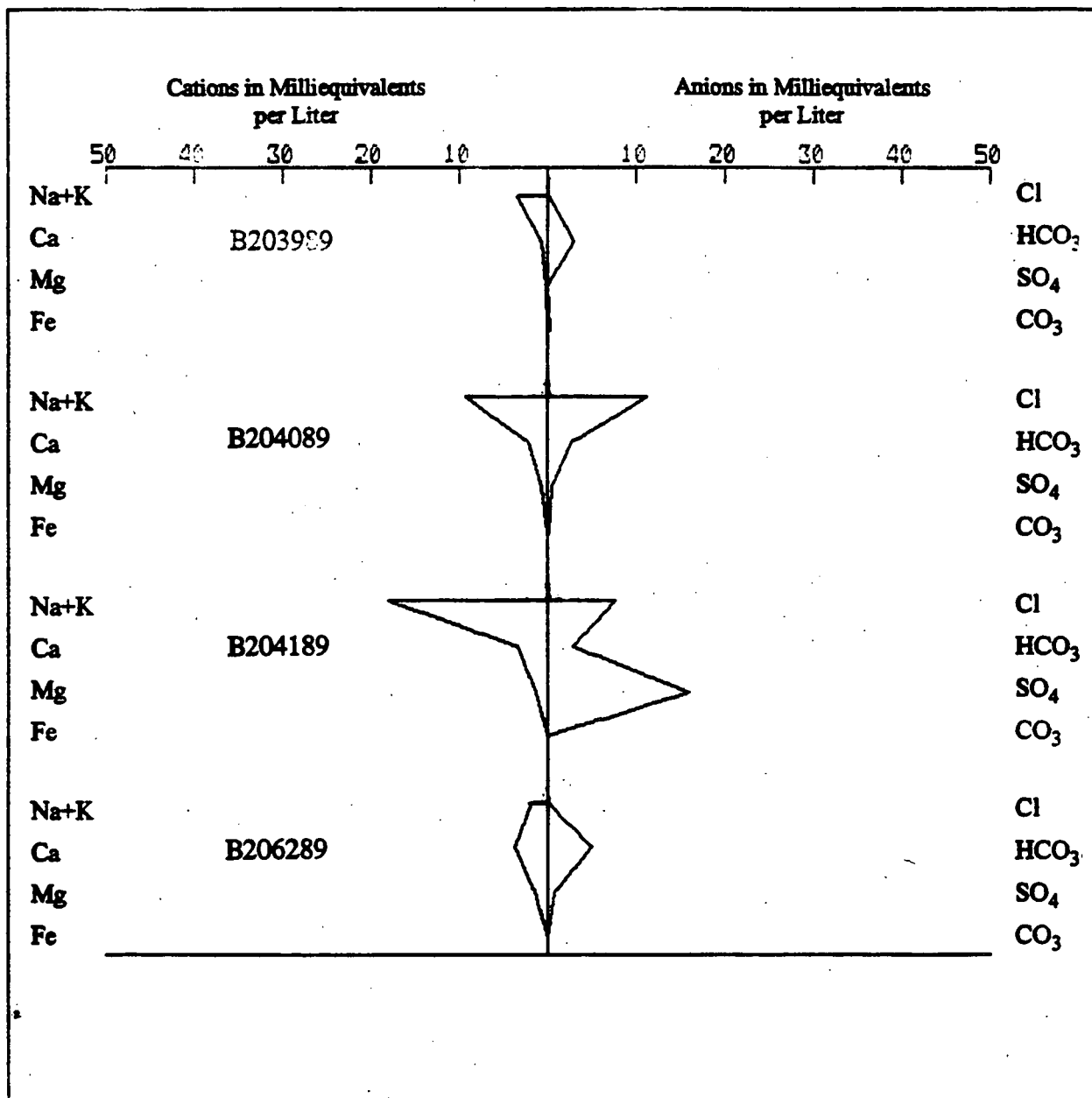
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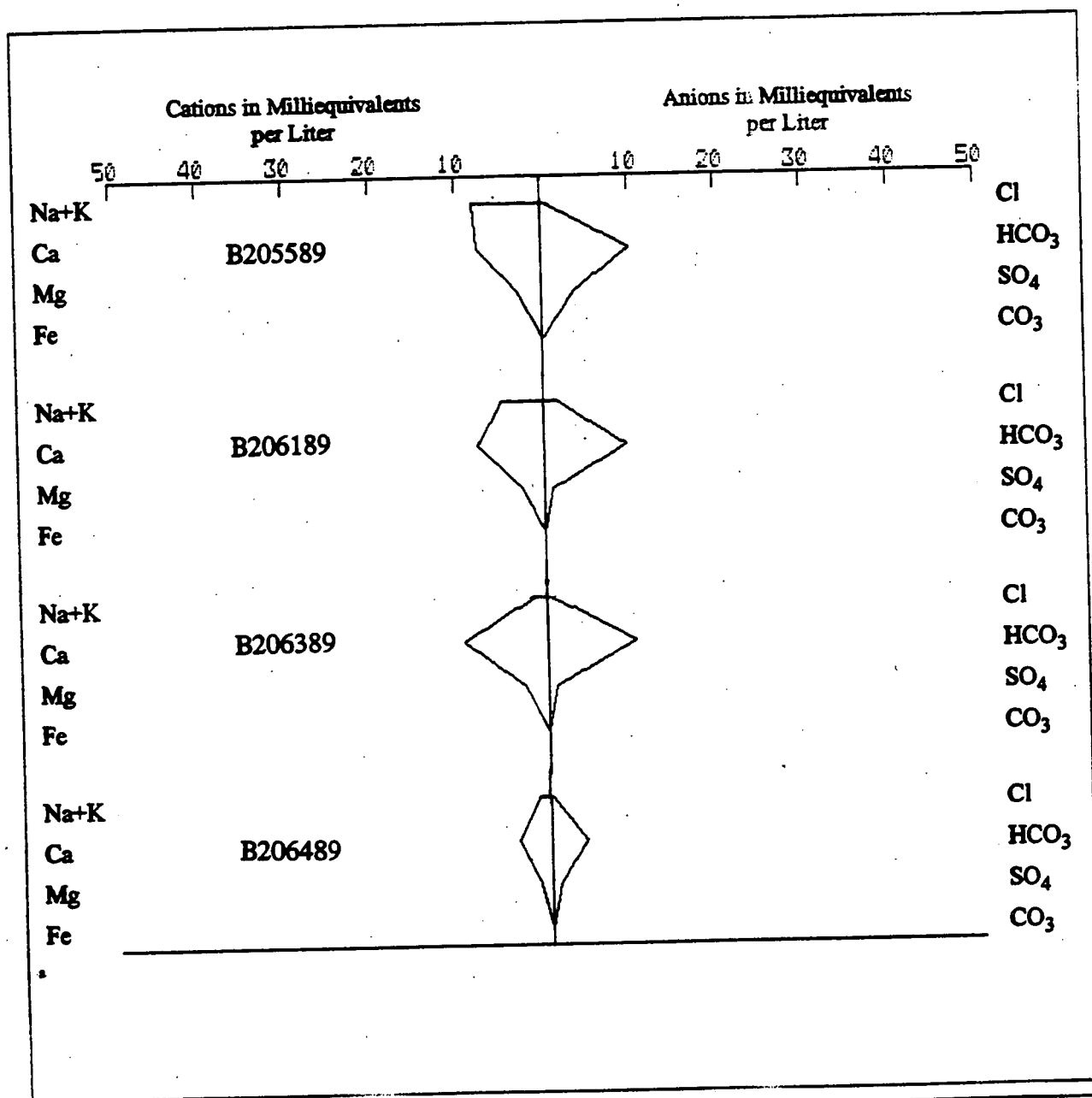
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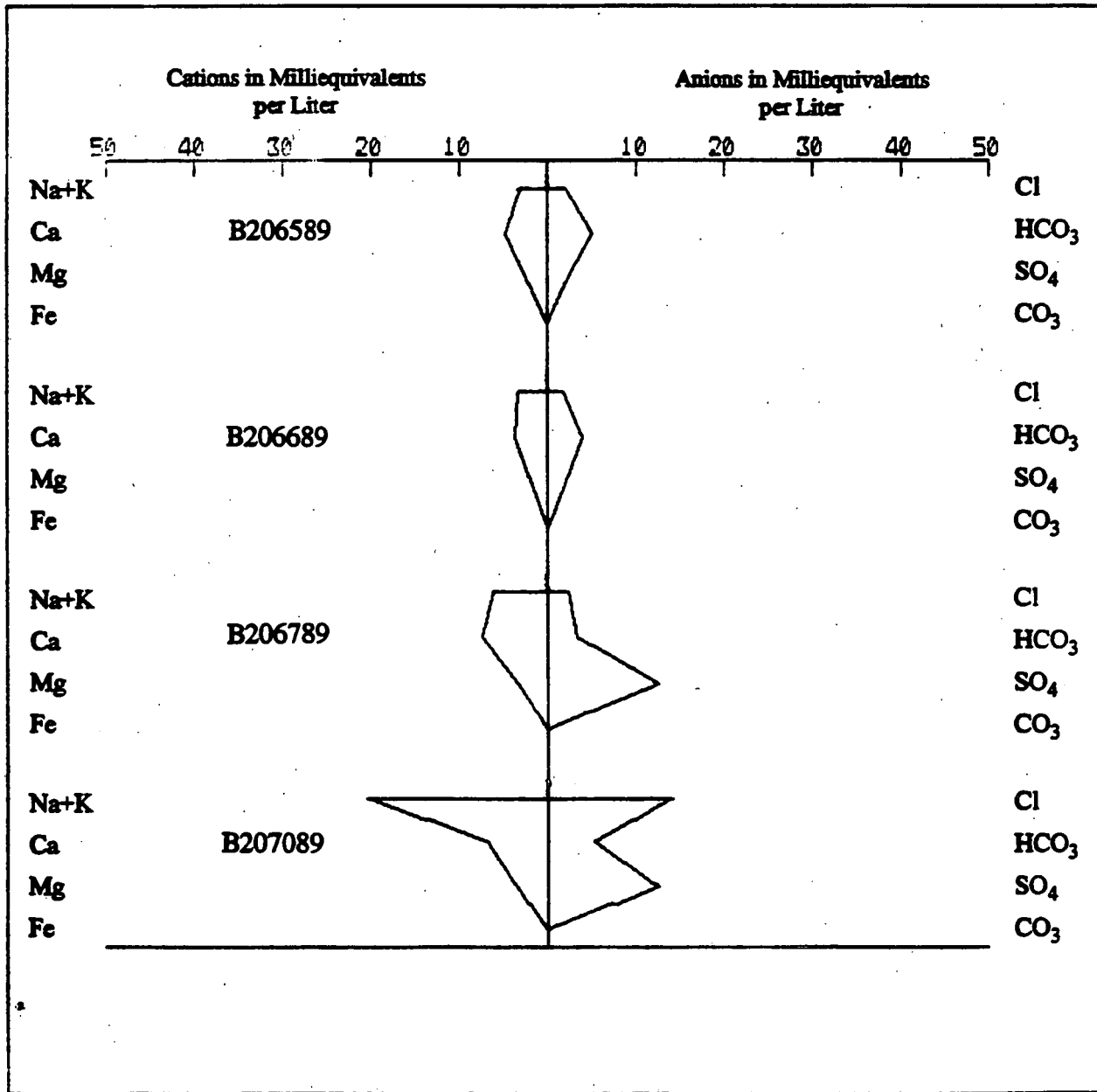


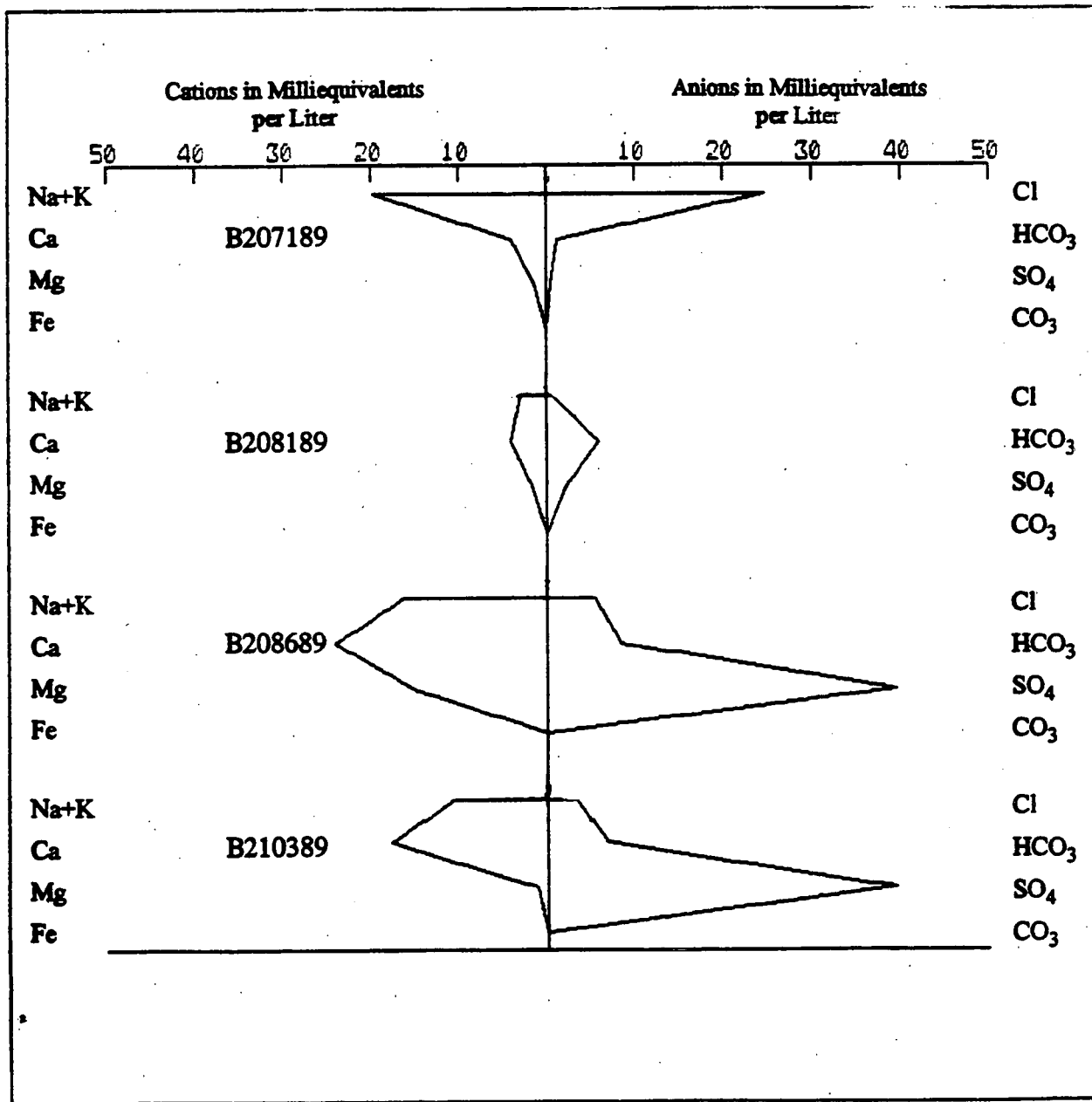
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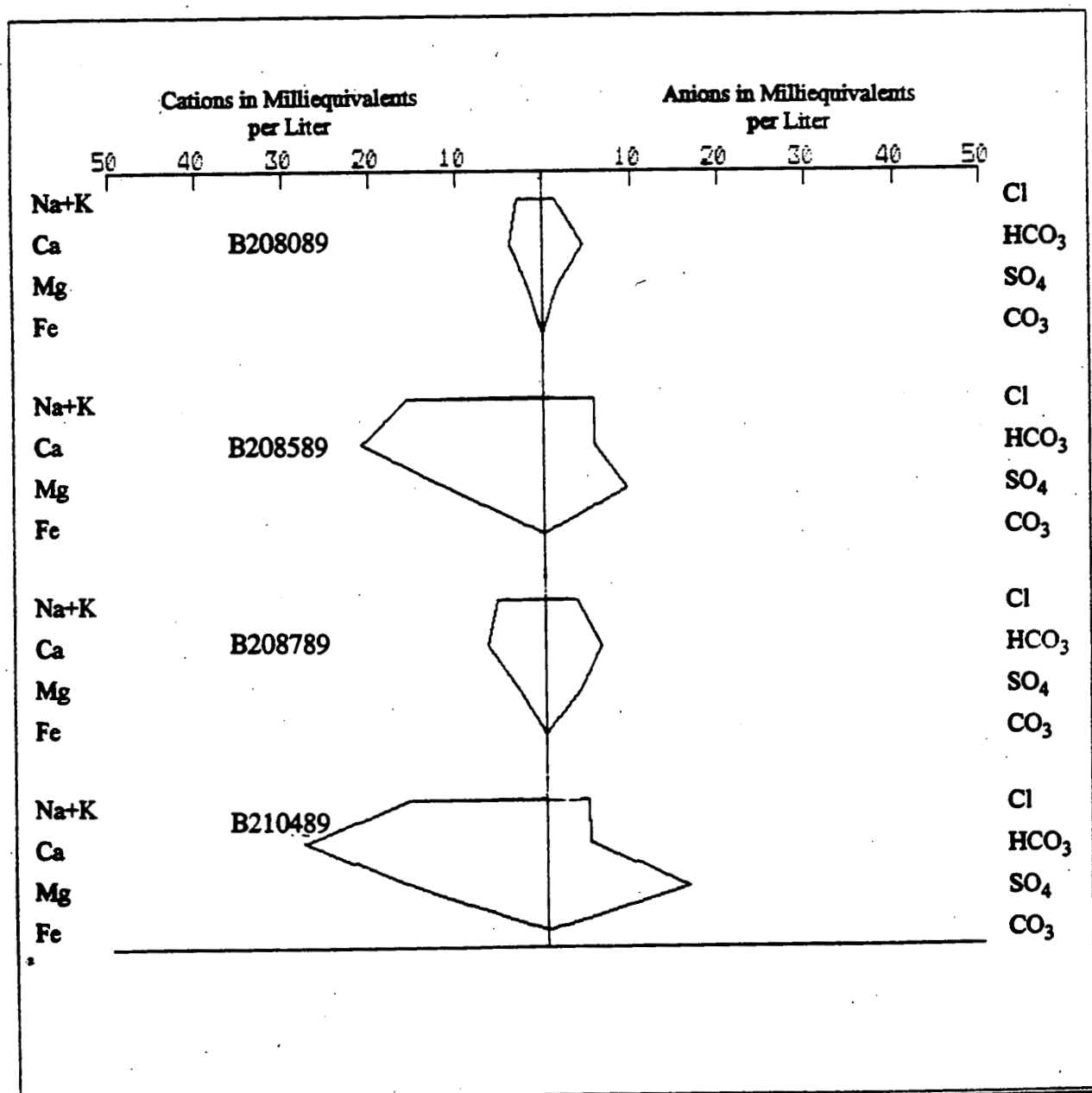




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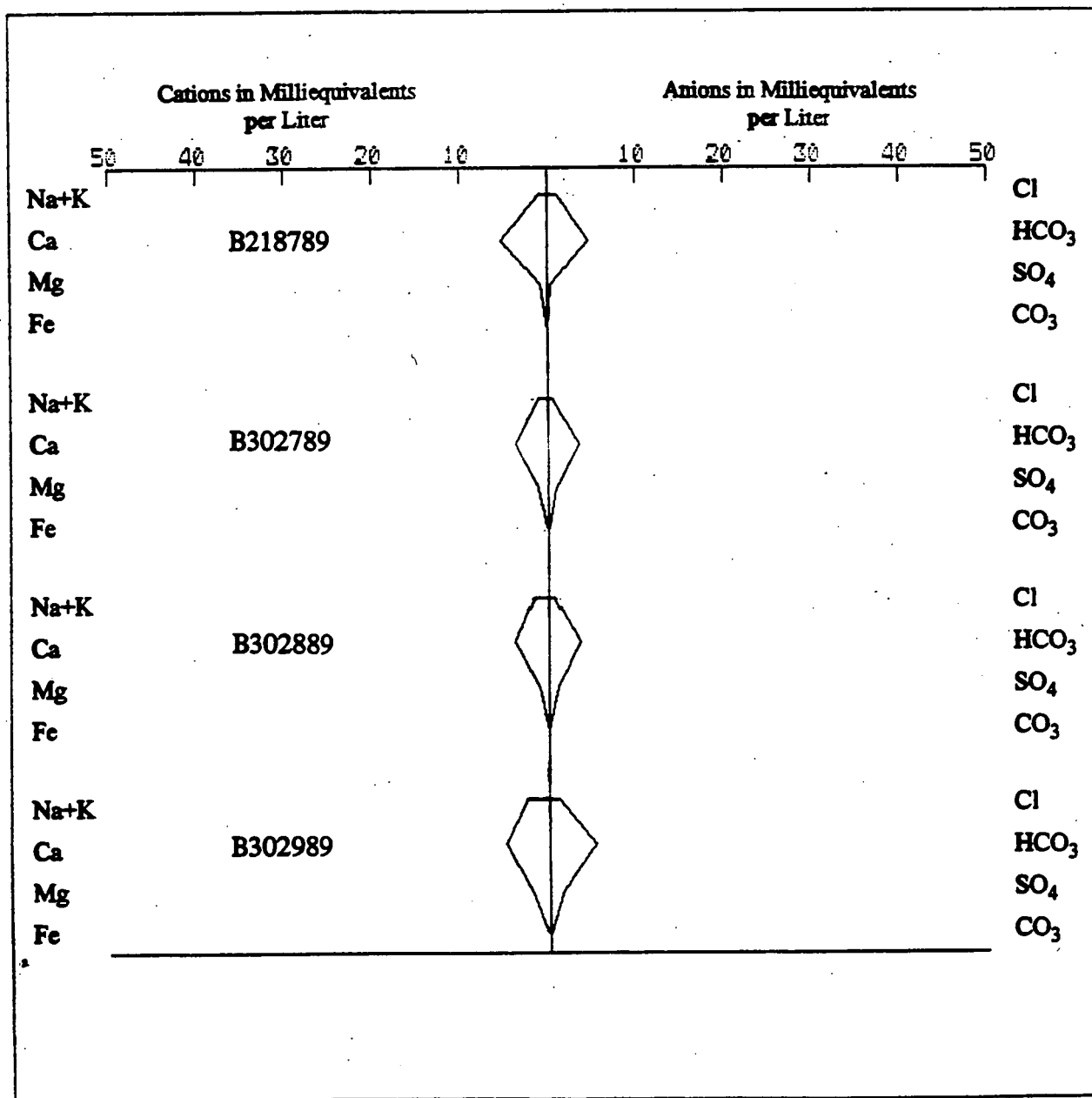






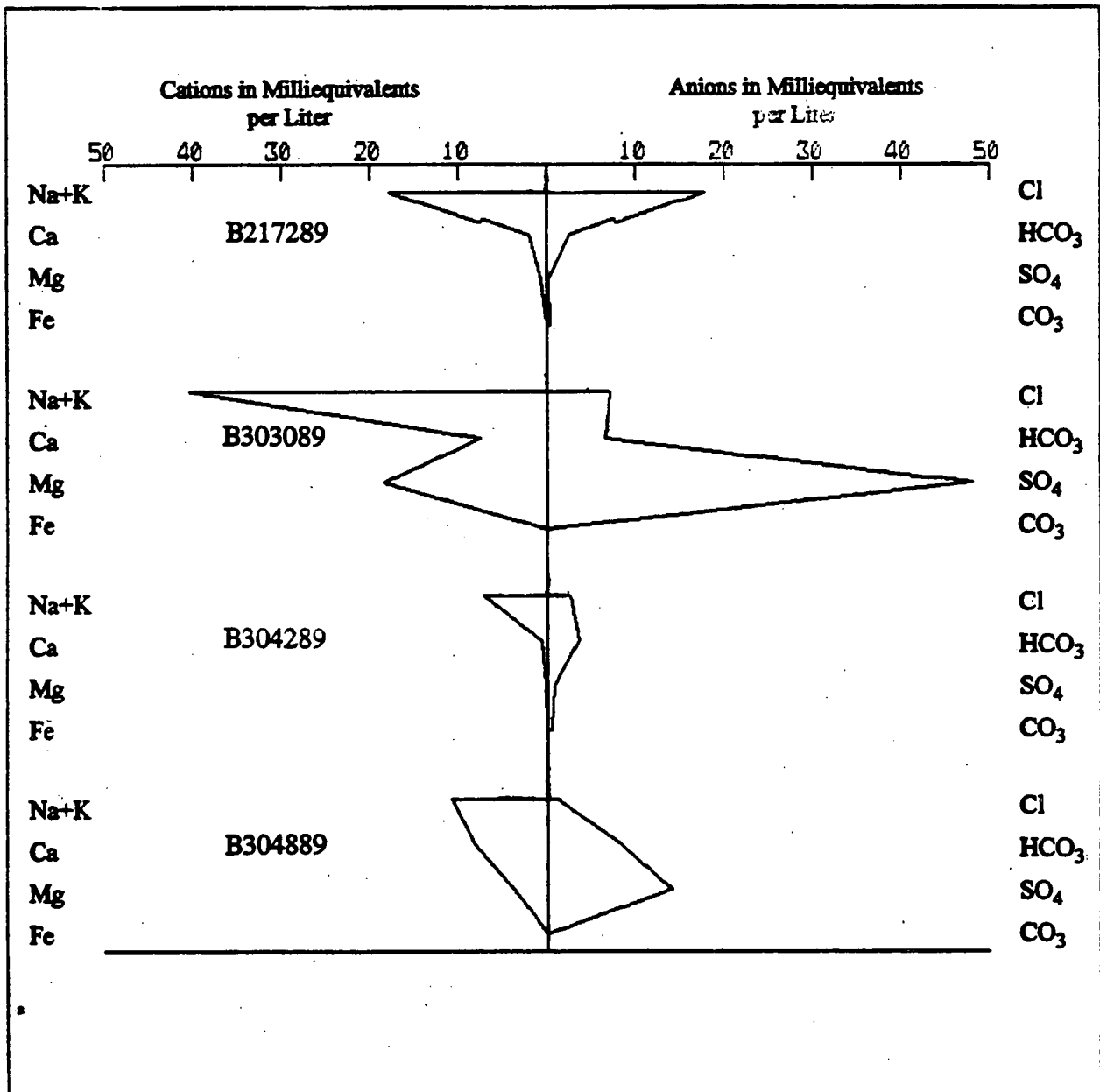
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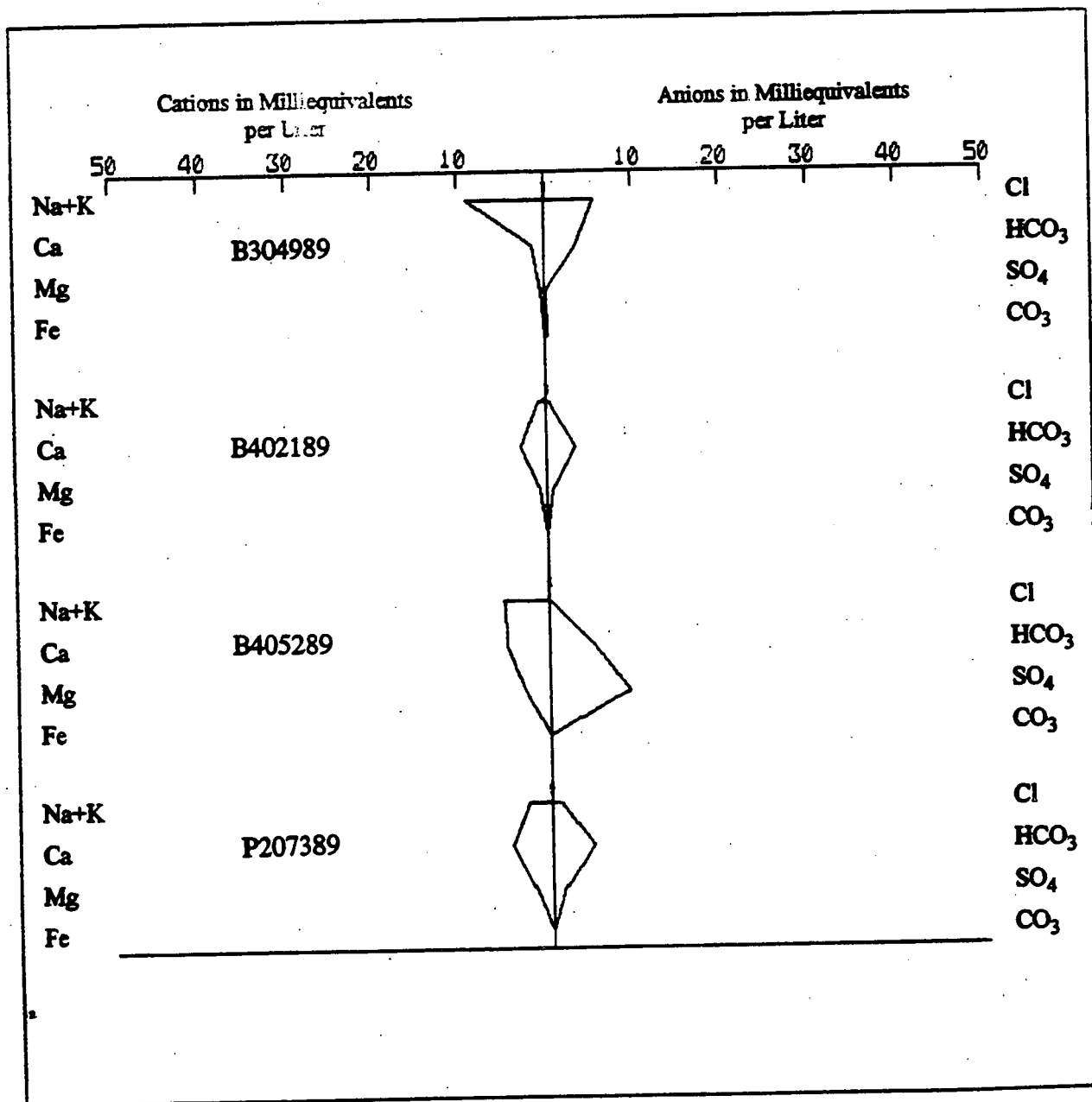


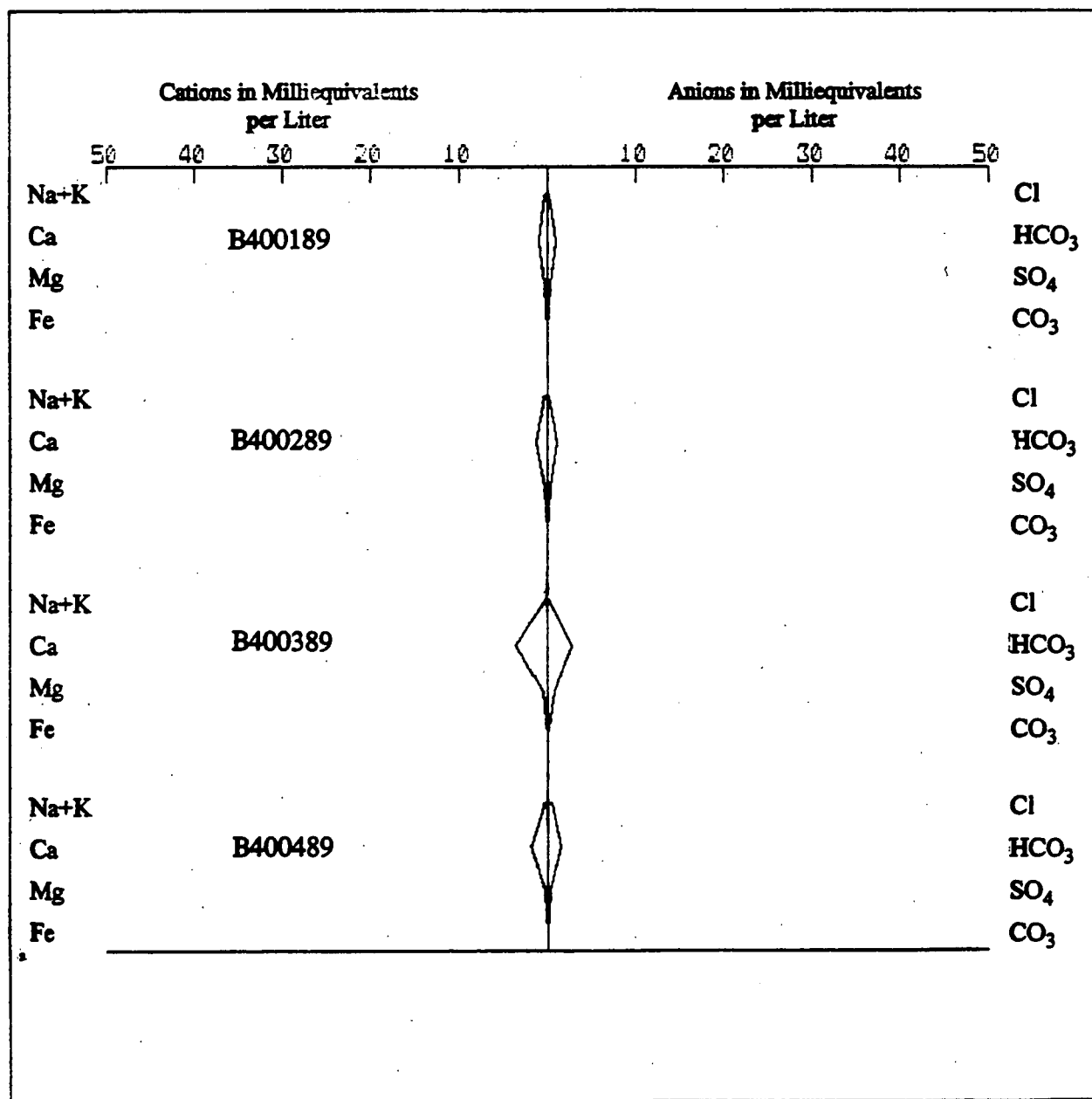
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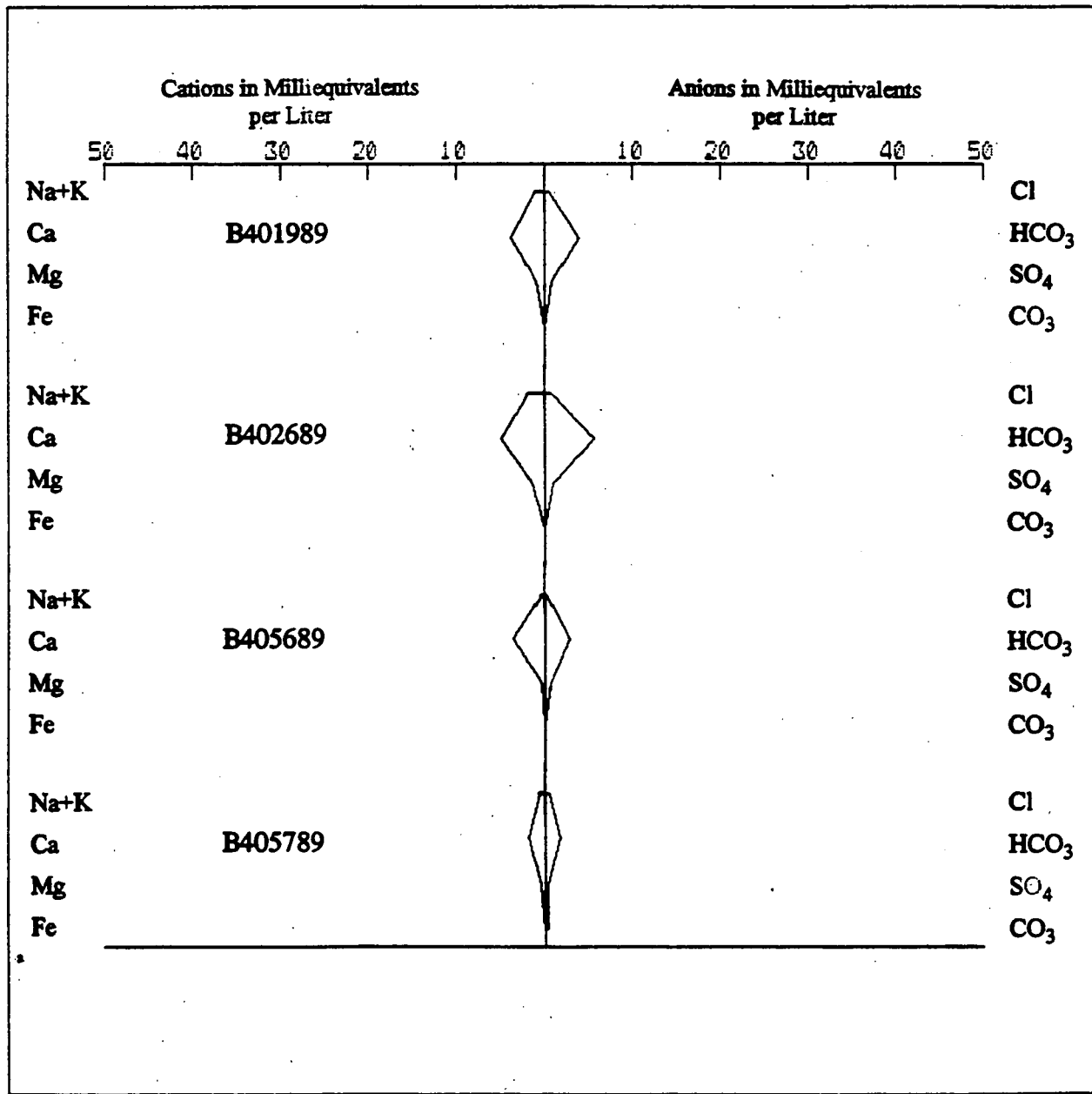




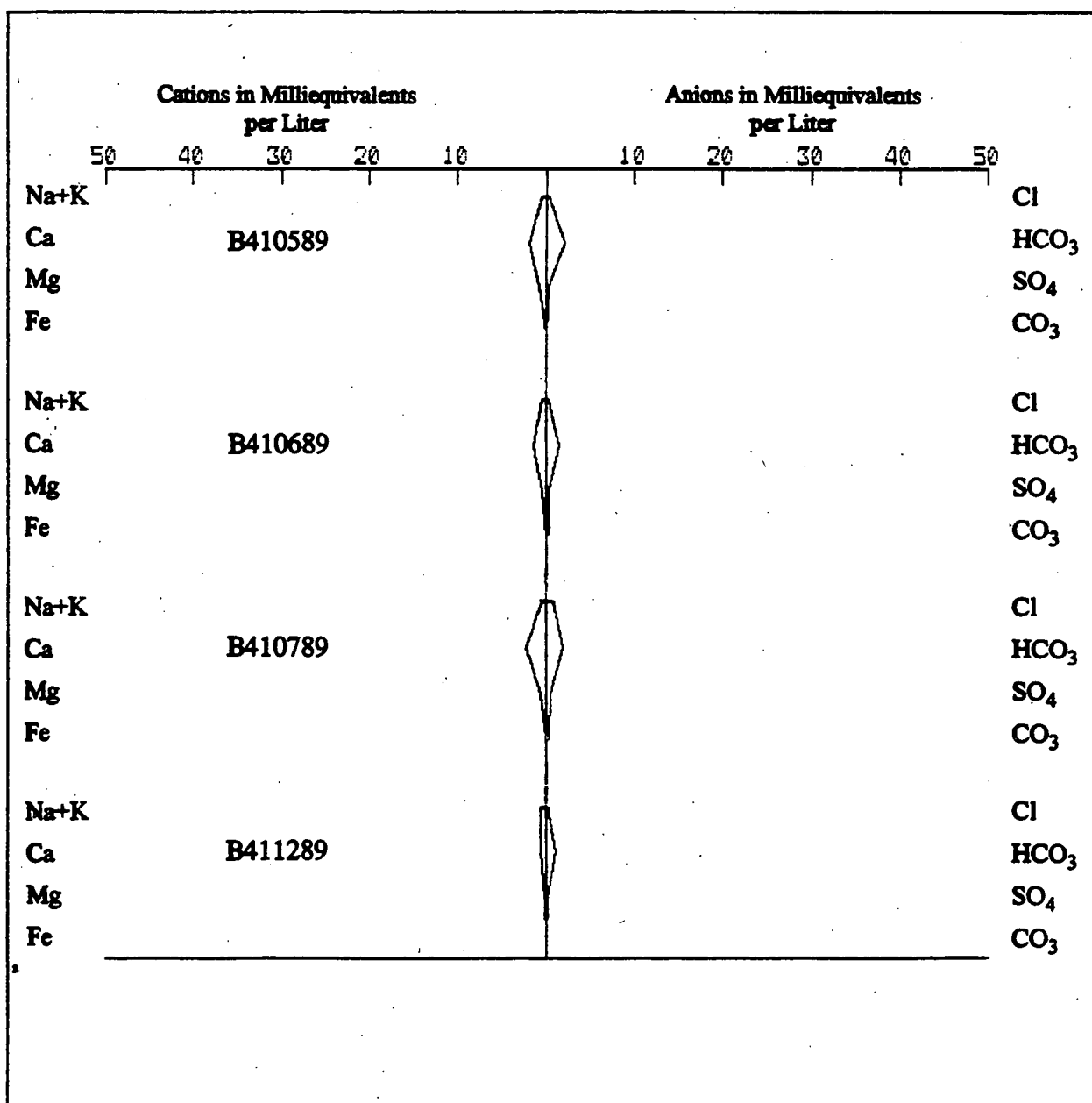


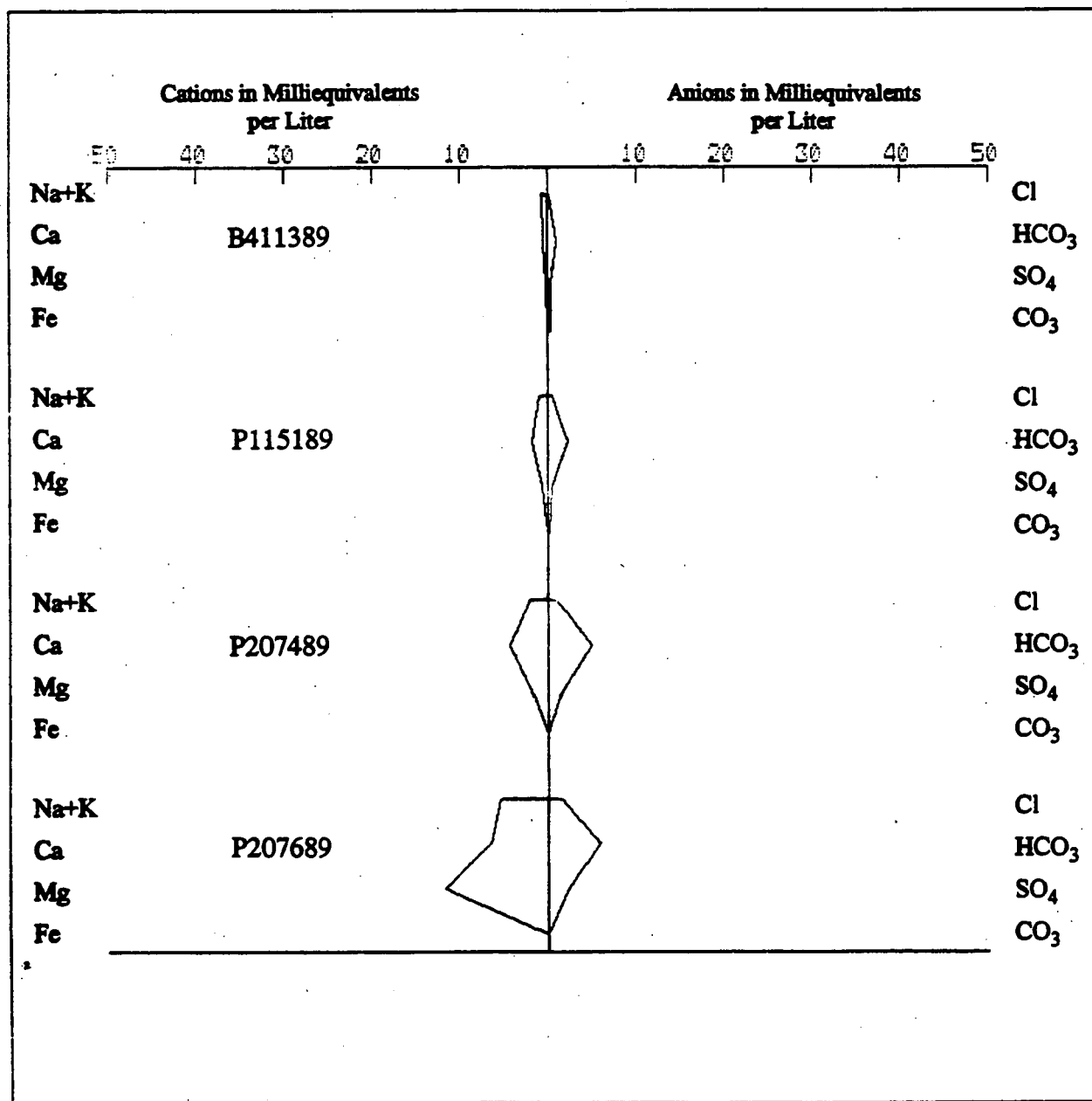
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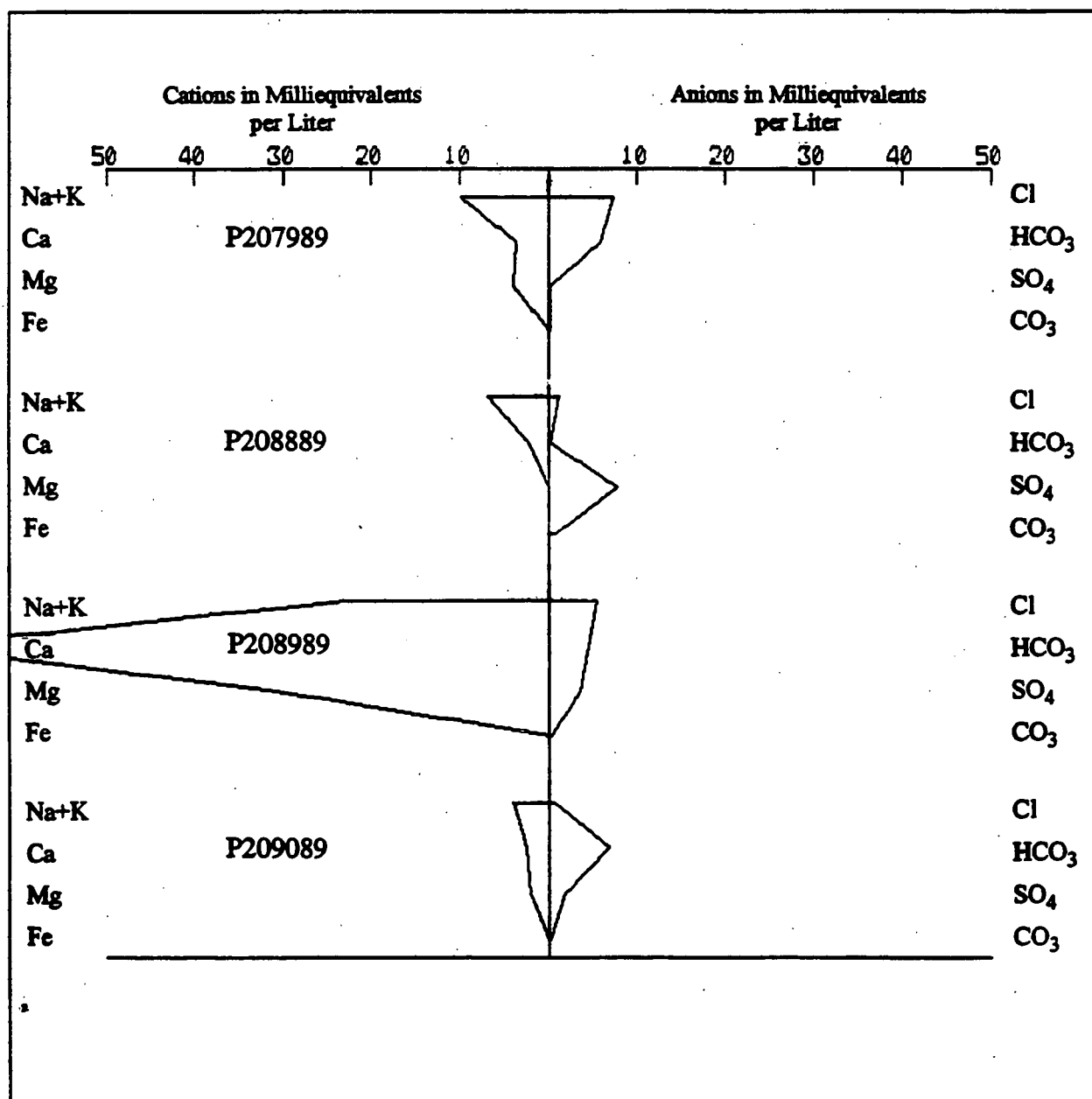


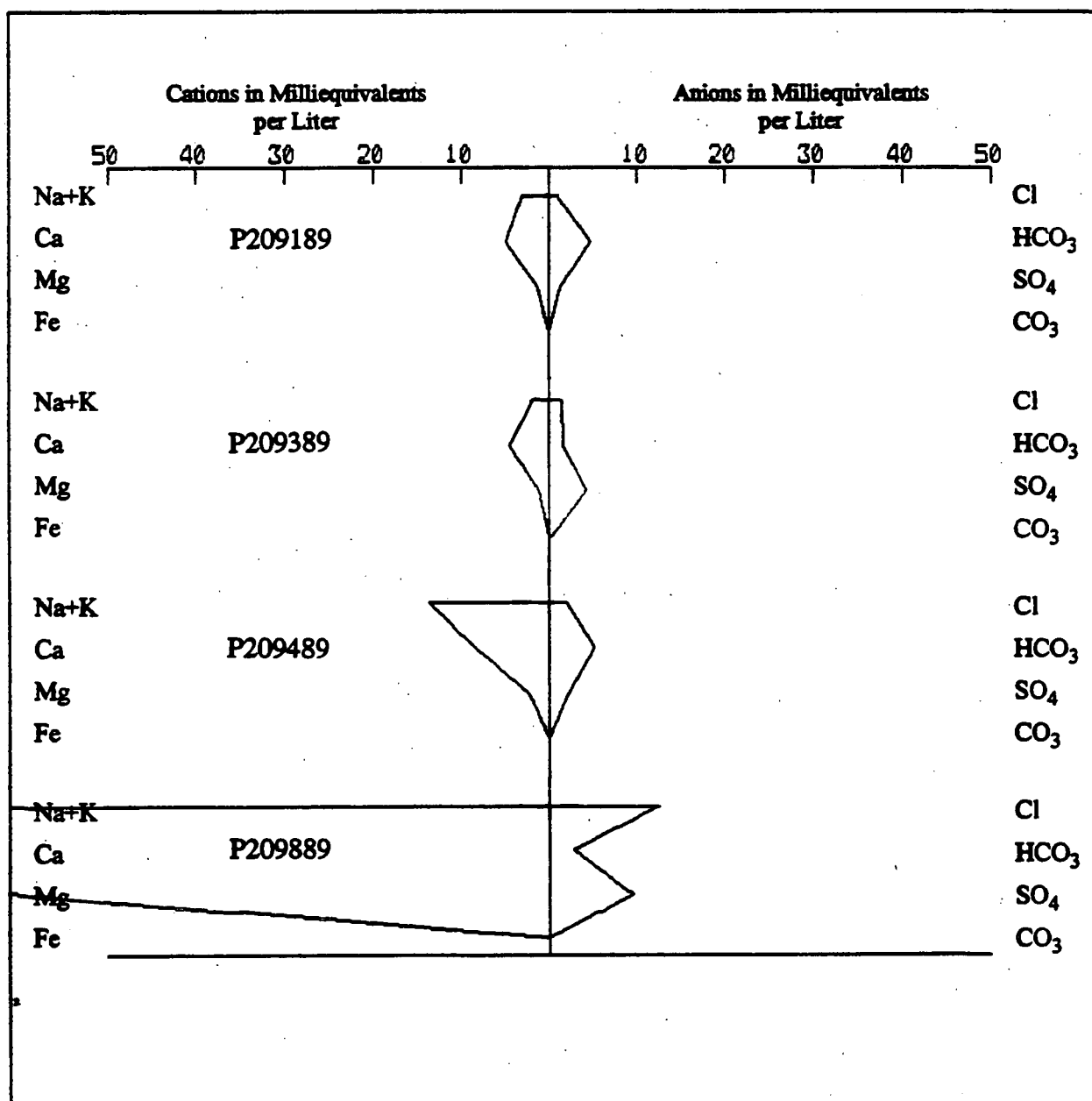
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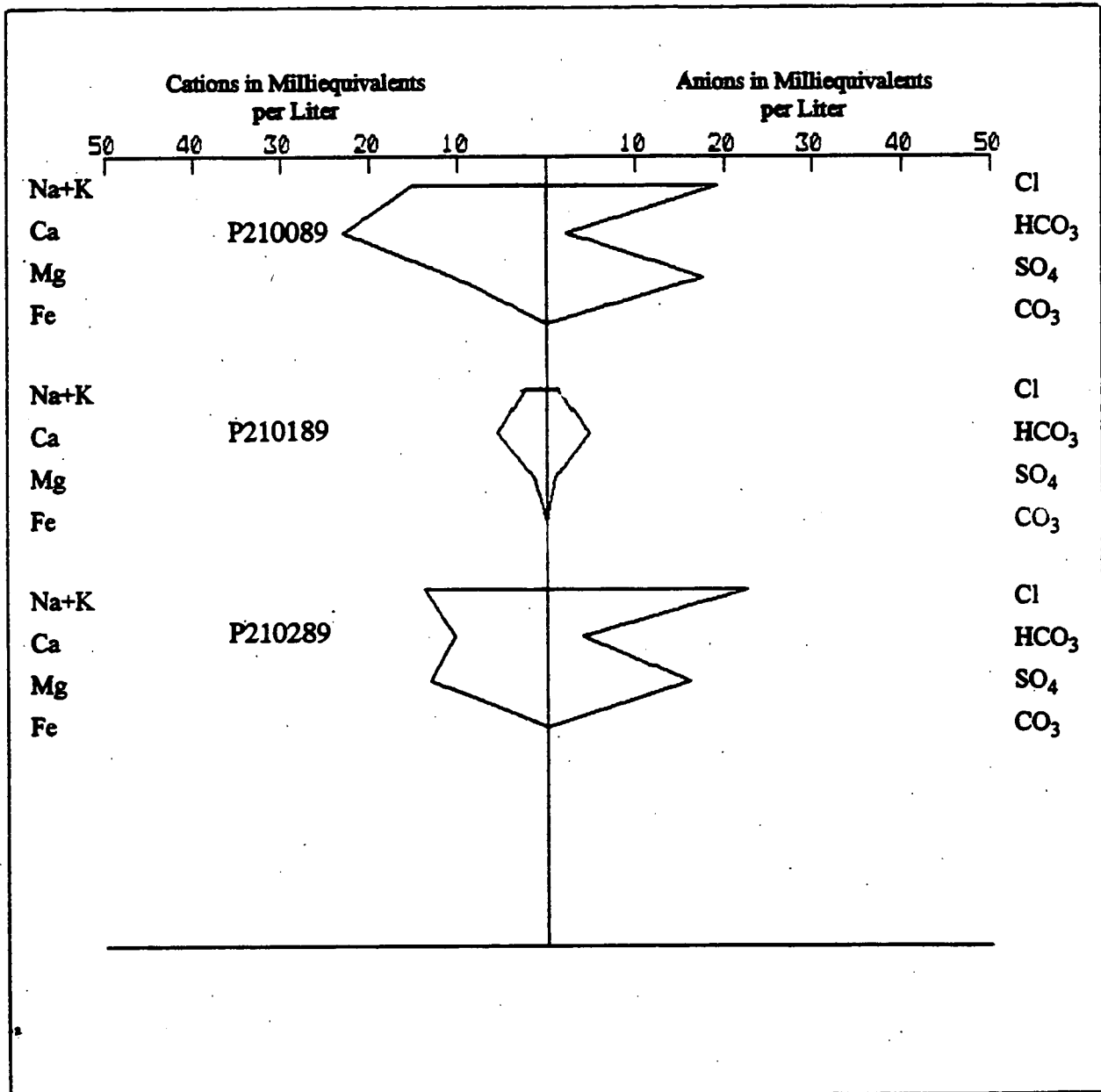




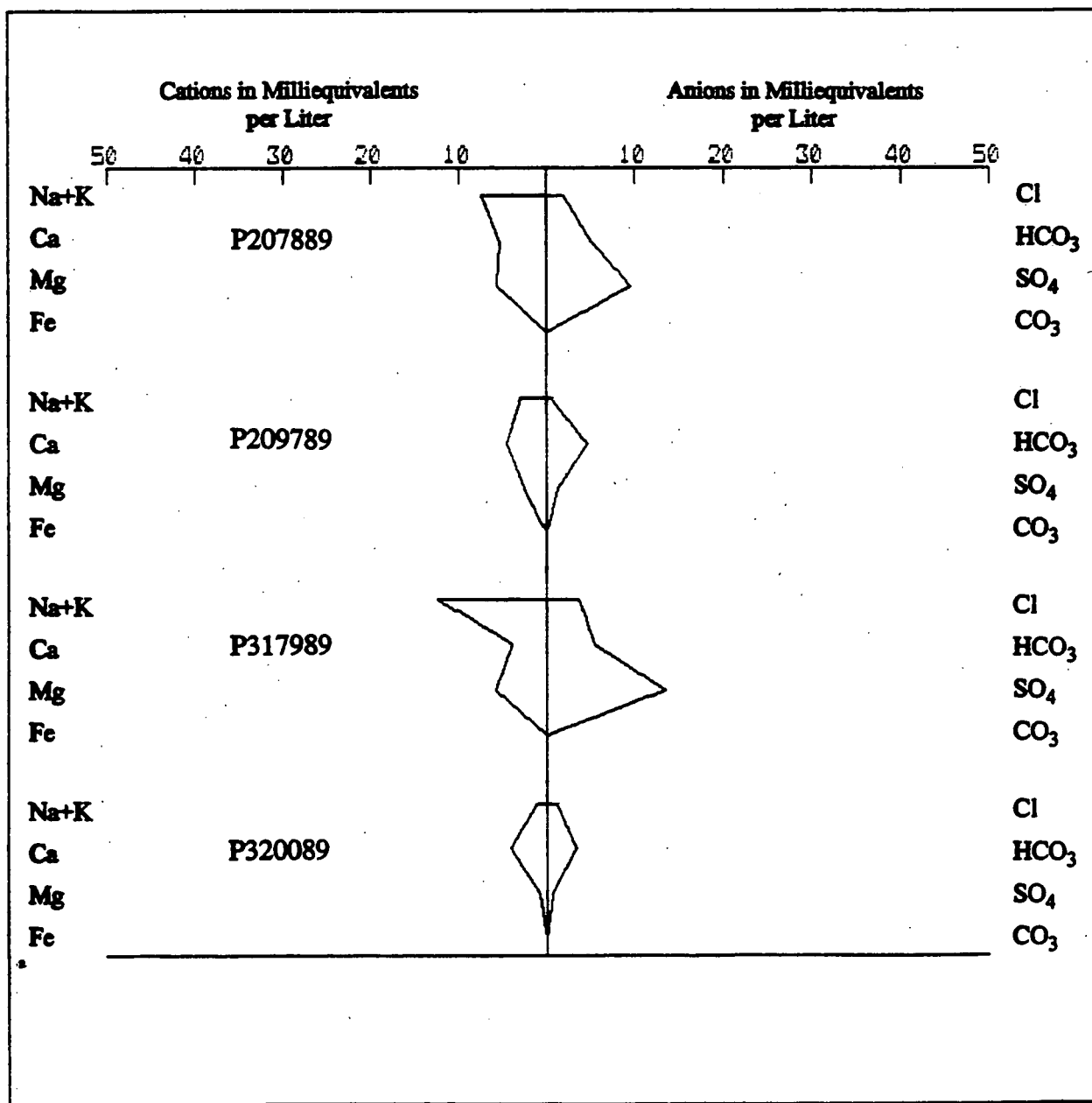
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**APPENDIX E**  
**LITERATURE REVIEW AND BIBLIOGRAPHY**

## **APPENDIX E**

### **1.0 INTRODUCTION**

A search of published scientific literature and unpublished, site-specific reports and documents has been conducted to identify sources of information relating to the hydrogeology and groundwater chemistry at the Rocky Flats Plant (RFP) and in its general vicinity. A search of the scientific literature was conducted to identify publications that provide either descriptions of groundwater chemistry or offer interpretations of chemical data specific to the RFP site. For each relevant document identified during this search, an abstract summarizing the purpose, data, and conclusions of the work described was prepared. Some of the documents identified were only relevant in a general, or regional, sense. These documents were included in a comprehensive bibliography, but no abstract was prepared.

### **2.0 SEARCH METHODS**

This search was conducted using a number of local libraries and their reference systems. The following libraries were used:

U.S. Geological Survey Library, Denver Federal Center  
EG&G Rocky Flats, Inc., Environmental Library  
Front Range Community College, Rocky Flats Reading Room  
University of Colorado, Norlin Library and Earth Sciences Library  
Colorado School of Mines, Arthur Lakes Library  
The S.M. Stoller Corporation, Environmental Services Library

At each library, the catalog system and the available reference databases (CD-ROM disc format) were searched. At the EG&G library the following reference databases were used:

1. PLUS, Enviro/Energyline Abstracts  
Copyright 1993, Bowker Electronic Publishing
2. National Technical Information Service (NTIS)  
NTIS Bibliographic Database, U.S. Department of Commerce  
Copyright 1987 - 1993, Silver Platter International N.V.
3. National Information Services Corporation (NISC)  
NISC, Water Resources Abstracts  
Copyright 1991, 1993, Rom Wright

4. NISC, Environmental Periodicals Bibliography  
Copyright 1972 - June 1993, Rom Wright
5. Dialog on Disc, Energy and the Environment Disc  
Copyright 1992 - April 1993, Dialog Information Services, Inc.
6. Dialog on Disc, Environmental Chemistry, Health & Safety  
Copyright 1992 - 1993, Royal Society of Chemistry, Dialog Information Services, Inc.

At the U.S. Geological Survey library the following additional databases were used:

7. GEOREF  
Copyright 1990 - 1993, American Geological Institute, Silver Platter International N.V.
8. Water Resources Abstracts, U.S. Department of the Interior  
U.S. Geological Survey  
Copyright 1991 - 1993, Silver Platter International N.V.
9. Earth Sciences Disc. 1975-1992  
Earth Science Data Directory, GEOINDEX  
Copyright 1992-1993, Silver Platter International N.V.
10. Publications of the U.S. Geological Survey as of March 1993  
Copyrights: 1992, American Geological Institute  
1989 - 1992, I-MODE Retrieval Systems, Inc.  
1983-1992, Personal Library Software, Inc.

Documents and reports listed in these databases were often accompanied by an abstract. In cases where this abstract was pertinent and well written, it was included with the compilation of abstracts and the appropriate database was referenced.

Abstracts have been included here for all documents providing information relevant to the hydrogeology and groundwater chemistry at the RFP. The abstracts are brief (approximately 100 to 250 words each) and emphasize the author's key findings pertaining to RFP hydrogeology and groundwater geochemistry. Each abstract states the purpose, describes the data collected, and states the interpretations and conclusions of the reports to the extent possible.

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Several unpublished documents include discussions of a broad spectrum of environmental topics and concerns at the Rocky Flats Plant (e.g., biological, ecological, geological, hydrogeological). Abstracts for these documents have been included, but the summaries focus on the data and conclusions that relate to groundwater issues. Other documents, both published and unpublished, contain groundwater information but either offer no new interpretations or are very general. These documents appear by reference in a comprehensive bibliography without an abstract. Several documents were identified in the search as relevant, but they were not successfully located at local libraries. These documents have also been included by reference in the comprehensive bibliography.

### 3.0 SUMMARY ABSTRACTS

Advanced Sciences, Inc. 1991. *Feasibility of Groundwater Cutoff/Diversion Study, Task 26 of the Zero-Offsite Water-Discharge Study*. Prepared for EG&G Rocky Flats, Inc. May 21.

In accordance with the Agreement in Principle between the Colorado Department of Health and the U.S. Department of Energy, the Zero-Offsite Water-Discharge Plan for RFP was developed. Included in the plan objectives is an assessment of the feasibility of groundwater cutoff/diversion in the area of RFP. A literature search on the geology and hydrogeology of RFP was conducted, and an annotated bibliography was compiled. Specific information on aquifer thickness and hydraulic properties is presented in tables. The feasibility study addressed four groundwater cutoff/diversion scenarios including: (1) a linear cutoff wall placed west (upgradient) of the Controlled Area; (2) a horseshoe-shaped cutoff wall placed around the west, south, and north sides of the Controlled Area; (3) a line of pumping wells at the east (downgradient) end of the Controlled Area; and (4) pumping wells on the downgradient edges of individual contaminant plumes. Flow net and stream line maps were developed to assess the effectiveness of the alternatives. The computer programs DREAM and SURFER were used to analyze the flow systems and contour the stream lines. The cost effectiveness of each alternative was also evaluated. This feasibility study concluded that installing pumping wells at individual contaminant sites is the recommended alternative for eliminating RFP contaminant discharges to the environment.

Advanced Sciences, Inc. 1991. *Non-Tributary Groundwater Study, Task 29 of the Zero-Offsite Water-Discharge Study - Draft Report*. Prepared for EG&G Rocky Flats, Inc. May 7.

This study was conducted to determine the physical and economic feasibility of pumping non-tributary groundwater from under RFP to replace water used at the facility and correct injured water rights for the assessment of the zero-discharge plan. Estimates for the volume

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of water (1,140 acre-foot/year) that needs to be replaced and/or augmented have been assumed. The calculated volume of water that can be withdrawn from the Laramie-Fox Hills aquifer would satisfy the needed volume of replacement water for the zero-discharge plan. In order to assess the feasibility of withdrawing water from the Laramie-Fox Hills aquifer, an analysis of a hypothetical well field at RFP was undertaken. Drawdowns in individual wells and at selected locations between wells were calculated using the Theis equation and superposition. Calculations made incorporating the hydraulic characteristics of the aquifer indicate that the proposed pumping rate would create a drawdown in excess of 700 feet; therefore, the actual withdrawal of the water is not feasible. The study concluded that it is more economically and physically feasible to purchase water from other sources. Graphs, charts, figures, and calculations support conclusions.

Advanced Sciences, Inc. 1991. *Surface-Water and Groundwater Rights Study in the Vicinity of Rocky Flats Plant, Task 14 of the Zero-Offsite Water-Discharge Study*. Prepared for EG&G Rocky Flats, Inc. May 21.

This water rights study was performed to analyze potential impacts to both surface water and groundwater rights downstream of RFP. Alternatives related to zero-offsite water discharge as well as alternatives to zero discharge from RFP were analyzed. RFP purchases trans-mountain and trans-basin water from the Denver Water Board. Disagreement exists over whether this water has to be returned to the South Platte River basin to satisfy downstream water rights. Non-tributary groundwater beneath RFP may be used to provide replacement or augmentation water to downstream water rights. Although the legally recoverable quantity of non-tributary groundwater in the Arapahoe and Laramie-Fox Hills aquifers underlying RFP has been estimated, including an extraction rate, much of this water may not be easily or economically extracted owing to hydrologic considerations. Data are presented on the estimated groundwater in storage beneath RFP. It is estimated that a total of 270,400 acre-feet of groundwater is stored beneath RFP in three aquifers: alluvium and valley fill; lower Arapahoe Formation; and the Laramie-Fox Hills Formations. The extent of bedrock aquifers in the vicinity of the site is presented on a figure. A compilation of wells registered with the state in the vicinity of RFP is also included.

Advanced Sciences, Inc. 1991. *Study of Water Resource Management, Rocky Flats Plant, Task 23 of the Zero-Offsite Water-Discharge Study*. Prepared for EG&G Rocky Flats, Inc. May 28.

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The objective of this report is to describe the applicable methodology for investigating and evaluating water resources management alternatives at RFP. This study focused on existing data and information sources relevant to developing an integrated planning system matching water demands with water sources, including groundwater.

Agency for Toxic Substances and Disease Registry, Atlanta, GA. 1986. *Health Assessment for Marshall Landfill, Boulder, Colorado, Region 8 - Final Report*, (CERCLIS No. COD980499255). June 12.

- \*\* The Boulder/Marshall Landfill has been the site of disposal of waste since before 1965. The site has been evaluated as a possible source of contamination, which may be a public health concern to the nearby population. The Agency for Toxic Substances and Disease Registry (ATSDR) has reviewed sampling data from the site and has found that the landfill has contributed to the contamination of groundwater under the site. Monitoring was limited to the groundwater immediately underneath the landfill and in the close proximity to the landfill. Samples taken from monitoring wells in and around the periphery of the site have shown elevated levels of metals, volatile organics, increased conductivity, and other indications that the groundwater has been affected by the materials in the landfill.

Aikin, A.R., and K.A. Turner. 1987. *Geochemical Assessment of Aquifer Recharge Effects in the Southwest Denver Basin*. Colorado Water Resources Institute Completion Report No. 146. September.

- \*\* Recharge of the Denver groundwater basin by injection has been proposed as a result of increasing depletion of the water supply. However, injection recharge can cause physical and chemical changes in the geologic materials of the recharged aquifer, depending on the chemistry of both the host and injected waters as well as the mineralogy of the aquifer's rock matrix. The Denver groundwater basin contains four principal bedrock aquifers, of which the Arapahoe aquifer is considered to be the best in terms of water quality and quantity. Some preliminary field injection tests have been undertaken using drinking water supplies. However, water that meets drinking water standards contains constituents which may react upon injection, resulting in aquifer damage. The field injection tests have demonstrated that permeability apparently decreases after a few hours, but the cause was not known. As a preliminary step in designing future field tests, analyses of aquifer water and Denver Water Board municipal drinking water were evaluated by a geochemical-equilibrium model (PHREEQE), developed by the U.S. Geological Survey, to determine the potential for

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reaction. The results of these simulations confirm that the Arapahoe aquifer is a good candidate for injection recharge. No fatal flaw appears to exist, from a geochemical standpoint, that would prevent the use of drinking water to recharge the Arapahoe aquifer.

Banta, E.R. 1989. *Hydrologic Effects of Pumpage from the Denver Basin Bedrock Aquifers of Northern El Paso County, Colorado*. U.S. Geological Survey Water Resources Investigations Report 88-4033. October.

- \*\* The Denver groundwater basin underlies a 6,700-square-mile area in eastern Colorado. To assess current conditions of the four bedrock aquifers in the basin, water levels, streamflow gain and loss, and other data were collected. Current aquifer conditions in the southern part of the basin and likely response to various 100-year pumping scenarios were analyzed using a digital finite-difference model. Simulated pre-development flow through the bedrock aquifers was about 59 cubic feet/second. Water-level changes between 1978 and 1985 likely caused by variations in precipitation, pumping, and by lowering of the water table in the overlying Black Squirrel Creek alluvial aquifer, ranged from rises of more than 40 feet to declines of as much as 80 feet. In 1985, pumping from the bedrock aquifers was about 56 cubic feet/second. Simulations indicate that 43 percent of the pumpage came from a decrease in volume of groundwater in storage; 37 percent came from induced recharge and captured discharge. The remaining 20 percent came from a transient high rate of recharge from precipitation. A baseline 100-year simulation, beginning in 1985, indicated minimal drawdowns for constant pumping at 1985 rates in the southern part of the basin. Other simulations indicated that the pumpage required to supply the needs of the projected population would be accompanied by drawdowns of as much as 1,300 feet and by large decreases in amount of groundwater in storage. Pumpage from a hypothetical well field, located where the aquifers are thickest, and from the aquifers underlying Colorado Springs also was simulated.

Belitz, K., and J.D. Bredehoeft. 1988. "Hydrodynamics of Denver Basin: Explanation of Subnormal Fluid Pressures." *American Association of Petroleum Geologists Bulletin*, Vol. 72, no. 11.

Anomalously low fluid potential (and hence subnormal fluid pressure) is found in Mesozoic and Paleozoic rocks of the Denver Basin. The potentiometric surface for the Dakota and basal Cretaceous sandstones is 2,000 to 3,000 feet (600 to 900 meters) beneath the land surface in parts of the Denver Basin in Colorado and Nebraska. The potentiometric surface

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for pre-Pennsylvanian carbonate rocks is 1,500 feet (450 meters) lower than the potentiometric surface for the Dakota Sandstone in southeastern Colorado and western Kansas. The low fluid potential seems especially anomalous considering the high elevation of the outcrops along the Laramie and Front Ranges and the Black Hills. A quasi-three-dimensional numerical flow model is used to investigate the regional flow system in the Denver Basin and adjacent mid-continent. The model simulates flow through the entire Phanerozoic sedimentary column and indicates that subnormal pressures are a consequence of hydraulic insulation of the strata within the basin from their recharge zones as compared to their discharge zones. The Dakota Sandstone and underlying hydrostratigraphic units are insulated from the overlying water table by low-permeability shales of Cretaceous age, and from their own high-elevation outcrops by a zone of low permeability coincident with the basin deep. Subnormal pressures in the area of Denver, Colorado, and southward are further enhanced by faulting along the Front Range that isolates the strata within the basin from their outcrops. The results of this study show that (1) subnormal fluid pressures can be explained as a consequence of steady-state regional groundwater flow, (2) shale is an important factor in the regional flow system, and (3) depth is an important control on the distribution of hydraulic conductivity.

ChemRisk. 1992. *Health Studies of Rocky Flats - Phases 1 & 2, Briefing Book 10-December 1992 - Project Task 6 Exposure Pathway Identification and Transport Modeling - Preliminary Draft Report, Rocky Flats Plant, Golden, CO.* Prepared for the Colorado Department of Health. November.

Groundwater has been identified as a possible exposure pathway because groundwater contamination has been documented at RFP. Groundwater can become contaminated through percolation of liquid effluent discharged to soil or holding ponds and leaching of buried waste. However, a complete assessment of the available groundwater information suggests that groundwater is not a significant transport mechanism of the materials of concern at RFP with regard to historical exposures. Exposure pathways associated with groundwater are incomplete at this time. This document compiles information resulting from a sitewide risk assessment study, ultimately identifying possible exposure pathways and modeling transport mechanisms for select contaminants of concern.

Cohen, R.H., D.M. Gilbert, and H.A. Wolaver. 1990. *<sup>239,240</sup>Pu, <sup>137</sup>Cs and <sup>210</sup>Pb Distributions in Colorado Front Range Lake Sediments.* A Report to the Rocky Flats Plant, Rockwell International, and EG&G. Department of Environmental Sciences and Engineering Ecology, Colorado School of Mines. May.

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Research was undertaken to measure  $^{239,240}\text{Pu}$ ,  $^{137}\text{Cs}$  and  $^{210}\text{Pb}$  in Colorado Front Range Lake sediments that were unaffected by the Rocky Flats Plant, Golden, Colorado. The results were compared to levels of similar isotopes of Pu and Cs reported in the Great Western Reservoir and Standley Lake, drinking water reservoirs downstream of RFP.  $^{210}\text{Pb}$  was used to obtain sedimentation rates in the lakes and the results were compared to Pu and Cs isotope determined rates. Global fallout as a result of atmospheric nuclear testing gave rise to maximum values of  $^{239,240}\text{Pu}$  in Wellington Lake of  $0.19 \pm 0.02$  pCi/gram of sediment and 0.074 pCi/gram in Halligan Reservoir. Maximum levels in the Great Western Reservoir were between 4.9 and 5.4 pCi/gram. Peak  $^{239,240}\text{Pu}$  activity levels in Standley Lake, downstream from RFP, were 26,300 pCi/square meter compared to 2,900 pCi/square meter for Wellington Lake and 610 pCi/square meter for Halligan Reservoir.  $^{137}\text{Cs}$  levels were actually lower in the Great Western Reservoir than in Wellington Lake or Halligan Reservoir. Considerably higher sedimentation rates reported for the Great Western Reservoir, three times or more than that of Wellington and Halligan, may result in sediment dilution of the isotopes such that the increase in mass of  $^{239,240}\text{Pu}$  over that in the background level lakes may be even higher in the Great Western Reservoir than suggested by comparison of maximum concentrations.

Crifasi, R.R. 1992. "Alluvial Architecture of Laramide Orogenic Sediments: Denver Basin, Colorado." *The Mountain Geologist*, Vol. 29, no. 1: 19-27.

Understanding the Denver Basin evolution and sedimentary structure may lead to an efficient development of the groundwater resources. The basin-wide Arapahoe, Denver, and Dawson aquifers existing in the non-equivalent Arapahoe, Denver, and Dawson Formations of the Denver Basin are defined by nuances of the sand/shale ratio in the sediments and detected by electric logging techniques. Isopach maps of aquifer units covering a 2,700-square-mile area of the Denver Basin have been compiled from 730 electric logs included in a database file at the Colorado Division of Water Resources. Comparison of the presented isopach maps to the sandstone/siltstone isolith maps shows a correspondence of thicker aquifer areas to thicker areas of sandstone and siltstone. The trends of greater aquifer thickness may be related to the general flow direction of the streams that deposited the sediment. Because these trends tend to channel the groundwater, the drawdowns of wells drilled into the same trend may adversely interfere with one another by causing the depletion of available water in the channel.

de Oliveira, R.B.B. 1975. "Exploration for Buried Channels by Seismic Refraction and Resistivity and Determination of Elastic Properties at Rocky Flats, Jefferson County, Colorado." Masters Thesis, Colorado School of Mines.

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Seismic refraction and electrical resistivity investigations at Rocky Flats, Colorado, a gravel-capped pediment, indicate an irregular bedrock surface with several ancient channels. The bedrock surface ranges in depth from 40 feet to 90 feet in the area west of the plant site. The ancient channels were located through seismic refraction, using the method of differences, Hale's method, delay time method, wave front construction, and Hawkins' method. There is good correlation between the depths to the bedrock obtained by the seismic and electrical methods. On the other hand, depths at which changes in velocity and resistivity occur within the gravel do not agree. The minimum group velocity and the high-frequency asymptote of a surface wave train are used for determination of the elastic properties of the overburden and substratum. The results agree with the elastic coefficients obtained from shear wave data.

Driver, N.E., and R.S. Williams. 1986. *Hydrogeology of and Potential Mining Impacts on Strippable Lignite Areas in the Denver Aquifer, East-Central Colorado*. U.S. Geological Survey Water Resources Investigation Report 84-4366.

- \*\* Strippable lignite coal seams, 20 to 60 feet thick, are present in the Denver Formation. The Denver aquifer, the saturated part of the Denver Formation, is likely to be affected locally by surface mining of lignite. Transmissivity of that aquifer in the study area ranges from 145 to 1,000 milligrams per liter as hydraulic head decreases from 6,600 to 5,400 feet. Distance-drawdown curves show the extent of water-level drawdown near a dewatered surface mine. After reclamation of the lignite mine pit, flow through the lignite spoil pile may increase the dissolved solids concentrations in the Denver aquifer. This increase could occur, because, as water from rain and overland flow percolates through the newly exposed rock surfaces in the spoil material, minerals from the overburden can be dissolved in the water, which then joins with water from the aquifer. This increase could affect streams, springs, and alluvial and bedrock aquifers locally.

EG&G Rocky Flats, Inc. 1990. *1988 Annual RCRA Ground-Water Monitoring Report for Regulated Units at Rocky Flats Plant - Addendum*. March 1.

Information previously unavailable during preparation of the 1988 Annual RCRA Groundwater Monitoring Report (1988 Report) includes geochemical data for the three RCRA-regulated units at RFP: Solar Evaporation Ponds (SEPs), the West Spray Field (WSF), and the Present Landfill (PL). Data not available include 1988 fourth-quarter metals data and third- and fourth-quarter radionuclide data. Updated tables originally presented in the 1988 report summarize concentrations of metals and radionuclides detected

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above background levels. The additional metals data support earlier interpretations of the nature and extent of metals contamination at these units. Above-background concentrations of radionuclides previously undetected were measured in groundwater from the SEPs. Similarly, elevated concentrations of uranium were observed in groundwater from the WSF and PL, although uranium was not previously detected above background at these locations.

EG&G Rocky Flats, Inc. 1990. *1989 Annual RCRA Ground-Water Monitoring Report for Regulated Units at Rocky Flats Plant*. Prepared by EG&G Environmental Management Department. March 1.

To determine the impact of waste management activities at three RCRA-regulated units at RFP (Solar Evaporation Ponds [SEPs], West Spray Field [WSF], and Present Landfill [PL]) on groundwater, 1990 groundwater data for each unit are statistically evaluated with respect to site background data. Upon evaluating the results, the current groundwater monitoring program is assessed for effectiveness, and recommendations are made for future monitoring. Groundwater data from 1989, as illustrated in supporting tables and figures, suggest that the SEPs most notably contribute TDS, nitrate, and dissolved uranium to the groundwater. The detection of these and other elevated constituents downgradient of the French drain indicates that the drain system is not effective in preventing contaminant migration. Further evaluation of this system is recommended. Groundwater data from the WSF suggest that spray application of liquid wastes from the SEPs has resulted in locally elevated concentrations of nitrate in alluvial groundwater. The PL appears to be contributing major ions, manganese, strontium, iron, tritium, and uranium to groundwater. Evaluation of the data and hydrologic investigations suggest that the groundwater intercept system at the PL may not be isolating the landfill from groundwater inflow.

EG&G Rocky Flats, Inc. 1990. *Final Background Geochemical Characterization Report, Rocky Flats Plant, Golden, CO*. Prepared for the U.S. Department of Energy. December 21.

Groundwater, surface water, sediment, and soil samples were collected from areas undisturbed by plant operations and analyzed to describe the geochemical characteristics of media collected from background locations. These data will be used to evaluate the nature and extent of environmental contamination in areas impacted by plant operations. Groundwater samples collected within the Buffer Zone west, north, and south of the plant were analyzed for radionuclides, metals, major ions, and water quality indicator parameters. Summary statistics and tolerance intervals are computed to describe separate groundwater

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units classified by geographic location and lithology (Rocky Flats Alluvium, valley fill alluvium, and weathered and unweathered bedrock). Various tables, plates, and figures (histograms, trilinear diagrams, etc.) summarize the analytical results and statistical analyses. Groundwater chemistry does not vary geographically, with the exception of chloride. Ongoing hydrogeological investigations indicate that groundwater beneath RFP consists of an upper and a lower flow system. Based on geochemistry, the upper flow system, which is characterized by bicarbonate to calcium carbonate waters, is comprised of the Rocky Flats Alluvium, valley fill, and weathered bedrock. The lower flow system includes unweathered bedrock and is characterized by water with relatively higher concentrations of sodium, potassium, chloride, and sulfate. Background groundwater chemistry appears good and may fluctuate seasonally. The tolerance levels presented here may be used by comparison with non-background data to help identify environmental media impacted by chemical releases from RFP. Data from chemical and statistical analyses are presented to support tolerance limit calculations.

EG&G Rocky Flats, Inc. 1990. *High Resolution Seismic Reflection Applications in Ground Water Monitoring Design, Rocky Flats Plant, Golden, CO*. Prepared for the U.S. Department of Energy.

The bedrock underlying the Rocky Flats Plant, Golden, Colorado is comprised of claystone, siltstone, and sandstone that were deposited by a complex fluvial system. Because of the heterogeneities inherent in such a complex stratigraphic system, monitoring networks should be based on an accurate reconstruction of the depositional system. The inherent costs for such a network prompted an evaluation of alternative methods to characterize the subsurface geology. Shallow, high-resolution seismic reflection was modeled and field tested in light of remedial investigation objectives to assess groundwater contamination. In addition, paleochannel morphologies, facies changes, and other stratigraphic and structural features not evident from borehole correlations were indicated. The current stratigraphic and depositional models are being re-evaluated to incorporate this preliminary seismic information. A conceptual three-dimensional geologic model, in addition to previously collected contaminant data, is being used to develop the monitoring networks at RFP.

EG&G Rocky Flats, Inc. 1991. *1990 Annual RCRA Groundwater Monitoring Report for Regulated Units at Rocky Flats Plant*. Prepared by EG&G Environmental Management Department. March 1.

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For the purpose of determining the impact of waste management activities at three RCRA-regulated units at RFP (Solar Evaporation Ponds [SEPs], West Spray Field [WSF], and Present Landfill [PL]) on groundwater, 1990 groundwater data for each unit are statistically compared to site background data. Upon evaluating the results, the current groundwater monitoring program is assessed for effectiveness, and recommendations are made for future monitoring. Data previously unavailable on groundwater elevation and water quality for 1989 are also evaluated as an addendum to the 1989 RCRA Groundwater Monitoring Report. A review of this supplemental data supports conclusions presented in the 1989 report. Groundwater data from 1990, as illustrated in supporting tables and figures, suggest that the SEPs contribute some inorganic compounds (nitrate), radionuclides, and volatile organic compounds (VOCs) to the groundwater. Detection of these constituents downgradient of the French drain containment system indicates that this system is not effective in preventing contaminant migration. Constituents detected above background concentrations in the groundwater beneath and downgradient of the WSF include inorganics, metals, and uranium. The PL appears to be contributing major ions, metals, radionuclides, and VOCs to shallow groundwater. Elevated concentrations of major ions (bicarbonate, TDS, calcium chloride, sodium) are present in weathered-bedrock wells.

EG&G Rocky Flats, Inc. 1991. *Final Groundwater Protection and Monitoring Program Plan for Rocky Flats Plant*. Prepared for the U.S. Department of Energy. November 27.

In accordance with DOE Order 5400.1, the groundwater protection and monitoring activities at RFP were evaluated; and a formal Groundwater Protection and Monitoring Program was developed. Included in the program are 371 wells and piezometers, of which 259 are sampled. The objectives of the program are to monitor concentrations of contaminants in groundwater, assess the rate of groundwater movement, and determine the location and extent of contaminant plumes. This program will be reviewed and evaluated annually and updated every three years. Essential for evaluating the Groundwater Protection and Monitoring Program is an understanding of the various monitoring activities at RFP, site geology, hydrogeology, and groundwater geochemistry, as well as all applicable state and federal regulations, orders, and agreements. The current status of the program, from the location of monitoring wells to presentations of data above sitewide background upper tolerance levels, is presented on maps and figures. Improvements to the program will be made as appropriate to comply with DOE requirements. Future decontamination and decommissioning plans expected at RFP will impact the design and implementation of the Groundwater Protection and Monitoring Program.

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EG&G Rocky Flats, Inc. 1991. *Geologic Characterization*. Prepared for the U. S. Department of Energy. July 31.

The hydrogeology of RFP has been characterized in an effort to aid the evaluation of groundwater flow parameters and contaminant migration pathways. The RFP generally lies within a regional groundwater recharge area with localized areas of discharge along seeps and in streams. The uppermost hydrostratigraphic unit consists of unconsolidated alluvial material, including Rocky Flats Alluvium, and valley fill alluvium, and subcropping sandstones of the Arapahoe Formation present beneath the alluvium. The lower hydrostratigraphic unit consists of unweathered bedrock of the Arapahoe and Laramie Formations composed primarily of sandstones and claystones. Hydrologic data on the claystones of the Arapahoe Formation indicate that the claystones exhibit low hydraulic conductivities and serve to confine much of the groundwater flowing within the lower hydrostratigraphic unit. A comparison of hydraulic properties for various geologic formations present beneath RFP indicates that the uppermost hydrostratigraphic unit exhibits low conductivities and that this unit is not considered a viable economic resource. Water-level maps of the uppermost hydrostratigraphic unit illustrate the hydraulic connection between the alluvial units and the subcropping Arapahoe sandstone. Information on depths to water indicate that groundwater flows beneath RFP towards the east. The hydrogeologic characterization is intended to provide input for hydrogeologic modeling, design of groundwater monitoring programs, and future remediation efforts.

EG&G Rocky Flats, Inc. 1991. *Rocky Flats Plant Site Environmental Report for 1989*. Prepared for the U.S. Department of Energy. February.

This report provides information to the public about the impact of RFP on the environment and public health and contains a compliance summary and results of environmental monitoring. Groundwater samples were collected from a network of 346 monitoring wells and analyzed for volatile organic compounds (VOCs), total dissolved solids (TDS), metals, and radionuclides as part of an environmental monitoring program. Contamination appears to be confined to local areas adjacent to past and present processing, storage, and disposal sites. These areas include the 881 Hillside, 903 Pad, Mound, and East Trenches, Solar Evaporation Ponds, and Present Landfill areas. Certain VOCs, metals, major ions, radionuclides, and TDS have impacted groundwater at RFP. The evaluation of the impacted groundwater indicates that no immediate threat to public waters exists at this time.

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EG&G Rocky Flats, Inc. 1991. *Rocky Flats Plant Site Environmental Report, January - December 1990*. Prepared for the U.S. Department of Energy.

This report provides information to the public about the impact of RFP on the environment and public health and contains a compliance summary, results of environmental monitoring, and an overview of other environmental studies and programs. Groundwater samples were collected quarterly from 258 wells and from the perimeter of the plant site. Samples are analyzed for select metals, volatile organic compounds (VOCs), radionuclides, water quality indicators, anions, and field parameters. Water levels were obtained monthly from 116 wells. Results from monitoring indicate that groundwater has been impacted locally at individual operable units where past and present site operations have taken place. These include the 881 Hillside; 903 Pad, Mound, and East Trenches area; Solar Evaporation Pond vicinity; and the Present Landfill area. Contaminants include VOCs, metals, total dissolved solids, nitrates, and radionuclides. The evaluation of the impacted groundwater indicates that no immediate threat to public waters exists at this time.

EG&G Rocky Flats, Inc. 1991. *Task 3 Shallow, High-Resolution Seismic Reflection Profiling in Operable Unit No. 2 (903 Pad, East Trenches, and Mound) at the Rocky Flats Plant - Final Report*. Prepared by EBASCO Services, Inc. February.

A shallow, high-resolution seismic reflection program uncovered three identifiable major channel zones. Two of these channel zones contain greater volumes of highly permeable sandstones than the more prevalent, surrounding low-permeability claystones and siltstones. These channel zones could provide potential bedrock contaminant pathways via groundwater flow.

EG&G Rocky Flats, Inc. 1992. *1990 Annual RCRA Groundwater Monitoring Report for Regulated Units at Rocky Flats Plant - Addendum*. Prepared by EG&G Environmental Management Department. March 1.

Information previously unavailable during preparation of the 1990 Annual RCRA Groundwater Monitoring Report (1990 Report) includes geochemical data (presented as tables and an appendix) for the three regulated units at RFP: Solar Evaporation Ponds (SEPs), West Spray Field (WSF), and Present Landfill (PL). Analytical results from all four quarters of 1990 for metals, volatile organic compounds (VOCs), inorganic ions, and radionuclides were evaluated and compared with earlier conclusions made regarding

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groundwater quality in the 1990 Report. As stated in the 1990 Report, groundwater data suggest that the SEPs contribute nitrate, certain radionuclides, VOCs, and metals to the groundwater. Data from the WSF sampling events support earlier conclusions that groundwater contains VOCs, as well as elevated concentrations of inorganic ions, metals, and radionuclides. Similarly, 1990 data for the PL support conclusions made in the 1990 Report that groundwater beneath this site contains VOCs, and elevated concentrations of major ions, metals, and radionuclides.

EG&G Rocky Flats, Inc. 1992. *1991 Annual RCRA Groundwater Monitoring Report for Regulated Units at Rocky Flats Plant*. Prepared by EG&G Environmental Management Department. March 1.

For the purpose of determining the impact of waste management activities at the three RCRA-regulated units at RFP (the Solar Evaporation Ponds [SEPs], West Spray Field [WSF], and Present Landfill [PL]) on groundwater, 1991 groundwater data for each unit are statistically compared to the site background data. Upon evaluating the results, the current groundwater monitoring program is assessed for effectiveness, and recommendations are made for future monitoring activities. Tables and various maps, including concentration contour maps, are used to present the data and make conclusions as to the extent of impact at each site. Groundwater quality data from 1991 indicate that the SEPs contribute inorganic ions, radionuclides, and volatile organic compounds (VOCs) to shallow groundwater, suggesting that the French drain system may not be preventing contaminant releases to groundwater. Data for the WSF indicate that this site may have contributed uranium, metals, and inorganics to the groundwater. Results of the 1991 groundwater monitoring program indicate that the PL impacts groundwater flowing within surficial materials by contributing VOCs, radionuclides, metals, and major ions; however, weathered bedrock beneath the landfill appears unimpacted. Data indicate that the groundwater intercept system appears effective in containing contaminants within the PL, except possibly along its south side.

EG&G Rocky Flats, Inc. 1992. *1991 Annual RCRA Groundwater Monitoring Report for Regulated Units at Rocky Flats Plant - Addendum*. Prepared by EG&G Environmental Management Department. August.

Data on groundwater quality for the three RCRA-regulated units (Solar Evaporation Ponds [SEPs], West Spray Field [WSF], and Present Landfill [PL]) unavailable during preparation of the 1991 Annual RCRA Groundwater Monitoring Report for Regulated Units at RFP

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(1991 Report) are evaluated to determine if the conclusions reached by the 1991 Report are supported. Data presented in tables and chemical distribution maps are compared to background water quality data to evaluate the extent of impact to groundwater associated with these regulated units. Additional data on groundwater quality for the SEPs show that VOCs and elevated concentrations of radionuclides and inorganic ions are present and support earlier conclusions that groundwater has been impacted by leakage from the SEPs. A statistical evaluation of the additional WSF data indicate that groundwater contains VOCs and elevated metals and uranium concentrations, which is consistent with earlier findings. Concentrations of radionuclides, inorganics, VOCs, and metals are consistent with levels reported in the 1991 Report. The occurrence of additional radionuclides will be evaluated in subsequent monitoring events.

EG&G Rocky Flats, Inc. 1992. *Background Geochemical Characterization Plan, Rocky Flats Plant, Golden, CO*. Prepared for the U.S. Department of Energy. February 28.

In order to monitor adverse impacts to the environment that may have resulted from past work practices at RFP, a structured program to investigate the background geochemistry of environmental media, including groundwater, was designed for RFP. Understanding the local hydrogeology at the site was imperative for the program design. Geologic media and groundwater from distinct geologic units will be sampled using standard techniques to establish possible sub-populations. Methods to collect and analyze (chemical and statistical) data are set forth. Analytical results will be analyzed to develop summary statistics and tolerance intervals for each analyte within each media. Recommendations for the geochemical and statistical evaluation of data are made.

EG&G Rocky Flats, Inc. 1992. *Background Geochemical Characterization Report, Rocky Flats Plant, Golden, Colorado*. Prepared for the U.S. Department of Energy. September 30.

In order to evaluate potential contamination in soil and groundwater at RFP, analytical results are compared with site background data collected from undisturbed, non-impacted areas by statistical analysis. Background geochemical data were collected from 1989 through 1992 in accordance with the Background Geochemical Characterization Program at RFP. Samples were collected quarterly from wells in north and south RFP and analyzed for radionuclides, metals, volatile organic compounds (VOCs), major ions, and several indicator parameters. Summary statistics and tolerance intervals were developed for each data set.

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Numerous plates, tables, and figures summarize site information, including analytical results and related statistical analyses. Groundwater at RFP consists of an upper flow system that includes the Rocky Flats alluvium, valley fill alluvium, colluvium, weathered bedrock, and a lower flow system consisting of unweathered Arapahoe/Laramie Formation bedrock. Geochemical plots (Stiff diagrams) of groundwater major-ion chemistry indicate that groundwater in unweathered sandstones is predominantly a sodium-sulfate type, whereas groundwater in the upper flow system is a calcium-bicarbonate type. The mean concentrations of many metals, radionuclides, and water quality parameters indicate significant differences in groundwater chemistry among lithologic units and geographical locations. Several spatial trends in total dissolved solid concentrations are observed within the upper flow system. Uncharacteristic major-ion chemistry is observed downgradient and locally north and south of RFP. Operable Units 2 and 7 may be influencing groundwater chemistry immediately downgradient of these units. The majority of analytes exhibited more significant differences among lithologic units than between locations (north versus south RFP). There were no VOCs detected in background groundwater. In addition, there were no systematic seasonal variations observed in background groundwater quality.

EG&G Rocky Flats, Inc. 1992. *Observations on the Occurrence of Plutonium and Americium in Ground and Surface Water, Rocky Flats Plant, 903 Pad, Mound, and East Trenches Areas, Operable Unit No. 2 - Draft Report*. Prepared for the U.S. Department of Energy. December 4.

Chemical analyses of groundwater and surface water samples collected from Operable Unit No. 2 reveal significantly lower groundwater plutonium (Pu) and americium (Am) activities than in surface water. These results suggest that discharging groundwater is not the single source of Pu and Am in surface water. Comparison of total and dissolved Pu/Am activities obtained from surface water samples indicates that more than one-half of the Pu/Am activity in surface water is associated with suspended solids. Graphical representations suggest a correlation between suspended solids and Pu/Am activity. The Pu/Am analytical data for groundwater and surface water are included in this report.

EG&G Rocky Flats, Inc. 1992. *Plutonium Measurements Near Background Levels, Rocky Flats Plant, Golden, CO*. Prepared for the U.S. Department of Energy.

\* The RFP is part of a nationwide nuclear weapons research, development, and production complex administered by the U.S. Department of Energy. Low levels of environmental plutonium occur in and around RFP as a result of past plant operations. Most of the plutonium analyses of media from RFP are at or near background levels. Measurements

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often show little, if any, plutonium in the media being sampled, including groundwater, except at known contamination sites. Measured plutonium activities are often less than the calculated minimum detectable level (MDL). (MDL is an *a priori* estimate of the activity concentration that can be practically achieved under a specified set of typical measurement conditions.) This paper investigates the relationship between plutonium activities and the counting uncertainty when measurements are near background, and suggests why the MDL should not be used as a criterion for limiting data. These issues involved in defining site background and determining attainment of standards are presented.

EG&G Rocky Flats, Inc. 1992. *Rocky Flats Plant Environmental Monitoring Plan, 1991*. March.

In accordance with U.S. Department of Energy requirements, an environmental monitoring plan was prepared for RFP. This document describes the Rocky Flats monitoring programs for groundwater, surface water, air, meteorology, soils, ecological and archaeological resources, gamma radiation, and procedures for dose assessment and quality assurance/quality control. The rationale, design criteria, and regulatory requirements for all monitoring programs are summarized. The groundwater monitoring program is summarized and includes background monitoring, RCRA/CERCLA monitoring, boundary monitoring, and characterization monitoring. The RFP has been monitoring groundwater since 1960 when the first six wells were installed near the Solar Evaporation Ponds. Samples have always been analyzed for radionuclides; in 1985, analyses for volatile organic compounds, metals, and major ions were added. The current site conditions, including well locations and aquifer thickness, are discussed in tables and figures.

EG&G Rocky Flats, Inc. 1992. *Rocky Flats Plant Site Environmental Report, January - December 1991*. Prepared for the U.S. Department of Energy.

This report provides information to the public about the impact of RFP on the environment and public health, and contains a compliance summary, results of environmental monitoring, and overview of other environmental studies and programs. Groundwater samples are collected quarterly from a network of monitoring wells spatially distributed throughout the plant site. Samples are analyzed for metals, volatile organic compounds (VOCs), radionuclides, water quality indicators, anions, and field parameters. Water-level measurements are obtained in conjunction with sample collection. Groundwater quality has

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been impacted locally at individual operable units where past and present waste operations have taken place. These include the 881 Hillside, 903 Pad, Mound, and East Trenches area, Solar Evaporation Ponds vicinity, and the Present Landfill area. Contaminants include VOCs, metals, total dissolved solids, nitrates, and radionuclides. The evaluation of the impacted groundwater indicates that no immediate threat to public waters exists at this time.

EG&G Rocky Flats, Inc. 1993. *1992 Annual RCRA Groundwater Monitoring Report for Regulated Units at the Rocky Flats Plant*. Prepared by EG&G Environmental Management Department. March 1.

For the purpose of determining the impact of waste management activities at the three RCRA-regulated units (Solar Evaporation Ponds [SEPs], West Spray Field [WSF], and Present Landfill [PL]) on groundwater, 1992 groundwater data for each unit are statistically evaluated. Analysis of variance tests comparing upgradient to downgradient water analyses reveal some significant variations in water quality at these units. Upon evaluating the results, the current groundwater monitoring program is assessed for effectiveness, and recommendations are made for future monitoring. Tables, contour maps, analytical data, and calculations support conclusions drawn regarding the nature and extent of groundwater contamination, groundwater flow direction, chemistry, contaminant migration rate, and other hydrogeologic characteristics at each RCRA unit. The results indicate that groundwater has been affected by leakage from the SEPs. Major contamination from the SEPs includes nitrate/nitrite, some volatile organic compounds (VOCs), gross alpha, gross beta, and tritium. Contaminants affecting groundwater at the WSF include <sup>233,234</sup>uranium, select dissolved metals, select inorganic analytes, and nitrate/nitrite. Contaminants to groundwater derived from the PL operations include VOCs, radionuclides, dissolved metals, and major inorganic ions.

Engineering-Science, Inc. 1974. *An Engineering Study for Water Control and Recycle*. Prepared for the U.S. Atomic Energy Commission. July 21.

This investigation was performed to provide a plant water-management plan designed to ensure that water-borne discharges from the RFP site will not be detrimental to the environment. One of the four major tasks of this investigation was to evaluate groundwater flow and subsurface transport of contaminants. The investigation also included location of existing and potential sources of groundwater contamination, evaluation of site hydrology, and review of current monitoring activities. Potentially impacted groundwater appears to

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flow through the pediment gravel that caps the relatively impermeable bedrock. The majority of groundwater is intercepted by the land surface and exits the site via streams draining the area. The principal source of potential groundwater contamination on the plant site is the process-waste collection and transfer system. Specifically, releases from the Solar Evaporation Ponds are known to be significantly impacting groundwater. Radionuclides are the primary contaminants of concern.

Engineering Science, Inc. 1975. *A Supplementary Report to an Engineering Study for Water Control and Recycle Concerning the Recovery of Nitrate Laden Groundwater, Rocky Flats, Golden, CO.* Prepared for the U.S. Atomic Energy Commission. January.

An investigation has been conducted to evaluate the transportation of nitrate salts from the 207 Solar Evaporation Ponds into North Walnut Creek. During the investigation, existing data were studied, exploratory drilling and well installation were completed, and chemical analyses of soil and water samples were obtained. Elevated concentrations of nitrates exist in soil and groundwater from throughout this area and are highest in a permeable lens of sand and gravel extending from the pond to the creek. Three approaches for the prevention of nitrate migration from the ponds are proposed. The recommended approach involves extending and improving the existing drainage system, capturing runoff, and maintaining low water levels in the pond to minimize nitrate migration. This alternative is also the most cost effective. Findings are supported by a collection of contour maps, cross-sections, and analytical data.

Evans, A., and W.L. Raley. 1984. *Research in Action: Solving Colorado Water Problems, FY 1983 Annual Report.* Colorado Water Resources Research Institute Annual Report No. 28. September.

- \*\* The Colorado Water Resources Research Institute conducted a single research project in Fiscal Year 1983 to integrate results of prior research on water management problems of the South Platte Basin. The results and products of this program will be transferable throughout the state and throughout the region. The principal objective of the project was to identify options for best development and management of the South Platte Basin's limited water supply. Emphasis was placed on potential for use of computer technologies. Team investigators considered urban and industrial water conservation, stream-aquifer modeling, water storage optimization, Denver Basin deep-bedrock groundwater, the quality of surface water and groundwater, economics of water allocation alternatives, legal-institutional aspects of water allocation, and current management practices. The institute's technology transfer

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program was fully integrated with its water research and development program. Water user workshops and seminars were conducted while the research project was in progress. A monthly Colorado Water Issues Forum was held in Denver, and authoritative speakers presented programs of current interest to water managers, professionals, and interested citizens. The institute's technology transfer program also includes newsletters; three publications series; distribution of a "Library List" of new water resources research reports and publications; Project AWARE, designed to keep state and federal agency personnel aware of proposed research; public water policy education (programs, including slide presentation); and workshops, seminars, and small group consultations involving potential users.

Evans, N.A. 1987. *Fiscal Year 1986 Program Report: Colorado Water Resources Research Institute Annual Report No. 23*. U.S. Geological Survey Water Resources Division.

\* The institute's federal Fiscal Year 1986 Program consisted of six research projects focused on the following Colorado problems: (1) conjunctive surface-groundwater management; (2) geochemical assessment of aquifer recharge effects in the southwest Denver Basin; (3) incentives for improving irrigation efficiency in the South Platte Basin; (4) specific yield of Denver Basin aquifer from nuclear magnetic resonance; (5) alternatives for meeting crane habitat requirements; and (6) reuse of treated wastewater by groundwater recharge.

Fedors, R.W., and J.W. Warner. 1993. *Characterization of Physical and Hydraulic Properties of Surficial Materials and Groundwater/Surface Water Interaction Study at Rocky Flats Plant, Golden, CO*. Colorado State University Groundwater Technical Report #21. July.

The movement of water in the subsurface at RFP is the focus of this report. Field and laboratory measurements made to characterize the physical and hydraulic properties of surficial materials at RFP, including saturated and unsaturated hydraulic parameters as well as measurements of physical properties of soils are reported for the Rocky Flats Alluvium, colluvium, and Recent alluvium. These parameters include measurements of saturated and unsaturated hydraulic conductivity, bulk density, laboratory measurements of water-retention curves, grain-size distribution, and saturated water content. The resulting values will assist in modeling efforts in the unconfined aquifer system at RFP. The investigation of surface water and groundwater interaction in the Woman Creek drainage quantifies the water flux between the creek and the unconfined system. As illustrated in a table, the magnitudes of net gains to or net losses from Woman Creek depend on which stream section is being monitored as well as the month. In general, the data from Woman Creek indicate that

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there is a net loss from the stream to groundwater in the summer, and a net gain during the winter months, possibly as a result of snowmelt as well as groundwater interaction.

Fedors, R.W., J.W. Warner, B. Roberts, and A. Berzins. 1993. *Numerical Modeling of Variably Saturated Flow and Transport - 881 Hillside, Rocky Flats Plant, Jefferson County, CO.* Colorado State University Groundwater Technical Report #20. June.

This study characterizes the unconfined groundwater flow and contaminant transport in colluvial and alluvial sediments on the 881 Hillside at RFP. Saturated and unsaturated hydraulic properties are estimated from laboratory measurements, field data, and literature values. A two-dimensional finite element code for variably saturated conditions is used to obtain steady state flow conditions from which water contents and Darcy velocities can be used for transient, contaminant-transport modeling. The migration of trichloroethene and tetrachlorethene detected in monitoring wells associated with past barrel storage activities is modeled over a 40-year period using alternative scenarios for the source area. Cross-sections were prepared to illustrate subsurface conditions using pre-1990 borehole logs. Based on the results of the numeric modeling, the scenario involving a mixed, dense, non-aqueous phase liquid (DNAPL) pool at the bedrock contact best explains the contaminant levels detected in monitoring wells. Data presented as tables and figures support this conclusion.

Fuhrmann, M., and P. Colombo. 1984. *Leaching of Solidified TRU-Contaminated Incinerator Ash.* Prepared for U.S. Department of Energy. Presented at the Annual Meeting of the American Nuclear Society, New Orleans, Louisiana. June 3, 1984.

Leach rate and cumulative fractional releases of plutonium were determined for a series of laboratory-scale waste forms containing transuranic (TRU) contaminated incinerator ash. The solidification agents from which these waste forms were produced are commercially available materials for radioactive waste disposal. The leachants simulate groundwaters with chemical compositions that are indigenous to different geological media proposed for repositories. In this study, TRU-contaminated ash was incorporated into waste forms fabricated with Portland type I cement, urea-formaldehyde, polyester-styrene, or Pioneer 221 bitumen. The ash was generated at the dual-chamber incinerator at RFP. These waste forms contained between  $1.25 \times 10^2$  and  $4.4 \times 10^2$  Ci (depending on the solidification agent) of mixed TRU isotopes comprised primarily of  $^{239,240}\text{Pu}$ . Five leaching solutions were prepared consisting of (1) demineralized water, (2) simulated brine, (3) simplified sodium-dominated groundwater (30 meq NaCl/liter), (4) simplified calcium-dominated groundwater

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(30 meq  $\text{CaCl}_2$ /liter), and (5) simplified bicarbonate-dominated groundwater (30 meq  $\text{NaHCO}_3$ /liter). Cumulative fractional releases were found to vary significantly with different leachants and solidification agents. In all cases forms that were leached in brine gave the lowest leach rates. Urea-formaldehyde had the greatest release of radionuclides while polyester-styrene and Portland cement had approximately equivalent fractional releases. Cement cured for 210 days retained radionuclides three times more effectively than cement cured only 30 days.

Hall, D.C., and C.J. Johnson. 1979. *Drinking Water Quality and Variations in Water Levels in the Fractured Crystalline-Rock Aquifer, West-Central Jefferson County, Colorado*. U.S. Geological Survey Water Resources Investigations Report 79-94. September.

- \*\* In parts of Jefferson County, Colorado, water for domestic use from the fractured crystalline-rock aquifer contained excessive concentrations of major ions, coliform bacteria, trace elements, or radiochemicals. Based on results of analyses from 26 wells, water from 21 of the wells contained excessive concentrations of one or more constituents. Drinking water standards were exceeded for fluoride in water from 2 wells, nitrate plus nitrite in 2 wells, dissolved solids in 1 well, iron in 6 wells, manganese in 8 wells, zinc in 2 wells, coliform bacteria in 4 wells, gross alpha radiation in 11 wells and possibly 4 more, gross beta radiation possibly in 1 well. Local variations in concentrations of 15 chemical constituents, specific conductance, and water temperature were statistically significant. Specific conductance increased significantly from 1973 to 1975 only in the vicinity of Indian Hills. Annual range in depths to water in 11 observation wells varied from 1 to 15 feet. The shallowest water levels were recorded in late winter, usually in February. The deepest water levels occurred during summer or fall, depending on the well and the year. Three-year trends in water-level changes in 6 of the 11 wells indicated decreasing water storage in the aquifer.

Hall, D.C., E.L. Boyd, and D. Cain. 1979. *Hydrologic Data for Wells, Springs, and Streams in Boulder County, Colorado*. U.S. Geological Survey Open-File Report 79-979. November.

- \*\* Hydrologic data collected from 1975 to 1977 as part of a comprehensive water-resources investigation of Boulder County, Colorado, by the U.S. Geological Survey in cooperation with the Boulder County Health Department and the Colorado Geological Survey are presented in this report. The data, in tabular and graphic form, consist of water-quality analyses of selected constituents and geohydrologic-site, water-treatment, and sewage-treatment data for 609 wells and 48 springs; water-quality analyses for 102 of the wells and

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9 of the springs; water-quality analyses of streamflow from 34 sites; and specific conductance and water-temperature measurements of streamflow from 3 sites. State and local officials in Boulder County may find these data useful in planning for residential, commercial, and industrial development.

Hall, D.C., D.C. Hillier, D.C. Cain, and E.L. Boyd. 1980. *Water Resources of Boulder County Colorado*. Colorado Geological Survey Bulletin 42.

Water resources in Boulder County are recharged by precipitation falling on the mountains and plains in this area. This study involved collection of surface and groundwater samples for major ion, trace element, bacteria, and radiochemical analyses to establish the suitability of the water as a drinking water supply. A study of the factors affecting the water quality was completed and long-term trends were evaluated. The data indicate that water quality has deteriorated in many areas and that there are both localized and widespread water-quality problems. Maps, charts, graphs, field and analytical test data are used extensively to supplement report findings.

Hoeger, R.L. 1968. "Hydrodynamic Study of the Western Denver Basin, Colorado." *Colorado School of Mines Quarterly*. Vol. 63, no. 1: 245-251.

\* The original hydrostatic pressure in the fracture system of Precambrian basement rocks in the Rocky Mountain Arsenal well was far below normal. In an effort to understand the reasons for the subnormal pressure, a study of hydrodynamic pressure gradients in overlying sedimentary rocks of the western Denver Basin was considered necessary. An analysis of all available data on the major deep aquifers is presented. A barrier trend, which may be caused by a fault system of regional extent, is present between the areas of high potential and the majority of the area studied, which is typically at much lower potential.

Hoffman N.D./Rockwell International/Energy Systems Group. Undated report. *Groundwater Monitoring at the Rocky Flats Plant, Golden, CO*.

Groundwater is monitored in 56 monitoring wells at RFP. Samples obtained are analyzed for select radionuclides, pH, nitrate, total dissolved solids, and approximately 43 other elements. Test results show that there is no significant groundwater contamination in most of the groundwater samples. Low concentrations of uranium, tritium, and nitrates above the

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background levels have been identified in the vicinity of the Solar Evaporation Ponds. The ponds may have been used to store waste water prior to treatment.

Hofstra, W.E., and D.C. Hall. 1975. "Geologic Control of Supply and Quality of Water in the Mountainous Part of Jefferson County, Colorado." *Colorado Geological Survey Bulletin* 36.

\*\* Information is presented on the availability of water for domestic supply in the mountainous area in Jefferson County, Colorado. The area covered by the study is approximately 300-square-miles of mountainous Jefferson County extending from Clear Creek on the north to the Pike National Forest boundary on the south and from the east edge of the Front Range mountains to the western boundary of the county. The population of the mountainous part of the county was approximately 20,000 in 1974. Hydrologic data were collected at 34 streamflow sites. Bacteriological and chemical analyses of surface waters are given for 32 sites. During the study, 31 springs and 727 wells were sampled. Comprehensive bacteriological and chemical analyses of samples collected from 38 wells and 1 spring are given. Eleven test wells were drilled by air-percussion. Geologic logs and hydrologic test data for wells are given. Analytical testing shows that water quality varies in different aquifers, and results indicate that water quality problems are related to the geology and hydrology of the mountain environment.

Hurr, T.R. 1976. *Hydrology of A Nuclear-Processing Plant Site, Rocky Flats, Jefferson County, Colorado*. U.S. Geological Survey Open-File Report 76-268.

The hydrologic setting of the RFP site and vicinity is important for evaluating potential impacts of plant operations and for predicting contaminant distribution within the hydrogeologic system. The presented precipitation, streamflow, stream sediment, water level, borehole, and surface geophysical data and geological and hydrogeologic maps compiled during this study have been incorporated with existing stratigraphic, structural, and hydrological data to evaluate the hydrologic system, recharge/discharge interactions, and erosional characteristics occurring at this site. A hypothetical model is used to demonstrate possible contaminant movement in the hydrologic system. The findings demonstrate that contaminants would move at different rates through different parts of the hydrologic system depending upon the magnitude of the release and the hydrological conditions at the time of the release.

Hydro-Search, Inc. 1986. *Electromagnetic Survey, Rocky Flats Plant, Golden, CO*.

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This report discusses the electromagnetic survey that was conducted along the periphery of the security area and the downgradient drainages and the buffer zone. It was performed along relatively constant geologic material so that the only variable would be the conductivity of the groundwater. The survey found several areas of relatively high ground conductance which appear to correlate with the areas of saturated surficial material encountered during the 1986 drilling program.

Hydro-Search, Inc. 1986. *Geological and Hydrogeological Data Summary, Rocky Flats Plant, Golden, CO*. Prepared for the U.S. Department of Energy.

The existing geologic, hydrologic, and water-quality data for RFP are summarized in this report. A description of the geology, both regional and local geologic setting, groundwater hydrology, groundwater chemistry, and surface-water hydrology are included. This information is based on previously collected data and reports, and this document includes a complete reference to all known hydrologic and soils reports. Figures, tables, and plates cover cross-sections, water table conditions, possible contaminant source areas, surface water monitoring locations, details of existing monitoring wells at RFP, details of drawdown-recovery tests at the plant, groundwater sampling program, and monitor well locations at the plant.

Hydro-Search, Inc. 1988. *Front Range Lightweight Aggregate Project, Official Development Plan, Written Restrictions, Supporting Documentation*. Prepared for L.C. Holdings, Inc.

The report outlines a zoning plan and has been prepared in response to the proposal made by L.C. Holdings, Inc. to reactivate and operate a shale, sand, and gravel open pit mine and processing plant (located along Colorado Highway 93 to the north of RFP). Characteristics of the surface water and groundwater hydrology of Coal Creek and the South Boulder Diversion Canal, the impact of precipitation on the surficial materials, and the hydrology of the Fox Hills Sandstone, Hygiene Sandstone member, and the Dakota Group sandstones are discussed in detail. A study regarding infiltration of water from the Rocky Flats gravels to the Coal Creek drainage basin and sub-basins has been made. Drainage design criteria and hydrologic data are included.

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Jaunarajs, S.R. 1991. "A Modeling Approach for Assessing the Feasibility of Ground-Water Withdrawal from the Denver Basin During Periods of Drought." Masters Thesis, Colorado School of Mines.

\*\*\* The groundwater resources in the shallow bedrock aquifers of the Denver Basin may be used to supplement water supplies for the expanding Denver metropolitan area. Previous research suggests that large-scale pumping on a continuing basis may deplete the basin's groundwater resources. Short duration pumping, however, designed to meet water deficits during drought periods, may be a feasible method of utilizing the resource without causing long-term groundwater depletion. A pre-existing computer model of the Denver Basin is calibrated and used to predict the decline in aquifer heads and stream baseflows as a result of drought period pumping from a proposed well field. The four bedrock aquifers in the upper portion of the section, the Dawson, Denver, Arapahoe, and Laramie-Fox Hills are modeled as separate units along with the major streams and valley fill alluvium in the basin. The MODFLOW computer code is used along with a modified river package, RIVINT, which permits simulation of variable river stage resulting from stream/aquifer interaction during transient simulations. Using known criteria, 6 drought periods with all but the last having a duration of 2 years, are identified during the 40-year interval 1948 through 1987, and then these historical cycles are imposed on the basin model for drought pumping simulations over the interval of 1990 to 2029. Annual water supply, use, reservoir storage, and change in reservoir storage for the City of Denver are examined for the years 1948 to 1987. Pumping rates are specified to eliminate deficits during droughts, such that no negative change in reservoir storage occurs during drought periods, assuming no growth in water use.

Lee, S.Y., L.K. Hyder, and P.D. Alley. 1987. *Mineralogical Characterization of Selected Shales in Support of Nuclear Waste Repository Studies: Progress Report*. Prepared for the U.S. Department of Energy. December.

\* Because baseline characterization of shale mineralogy is critical to the interpretation of results from experiments on radionuclide retardation, groundwater-shale interactions and physiochemical characteristics, a protocol for quantitative mineralogical analyses has been developed by integrating geochemical and instrumental techniques for the investigation of properties related to repository performance. Thermal analyses were used to estimate total organic matter and carbonate mineral contents. Scanning electron microscope backscattering and elemental mapping of polished sectors and particle-size distribution data were used to estimate the amounts of quartz plus feldspar and pyrite in the shales. X-ray diffraction, neutron activation, and size-distribution data were utilized to estimate

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phyllosilicate mineral contents. High-resolution transmission electron microscopy was used to identify clay mineral components.

Leonard, R.B., D.C. Signor, D.G. Jorgensen, and J.O. Helgesen. 1983. "Geohydrology and Hydrochemistry of the Dakota Aquifer, Central United States." *Kansas State Geological Survey Water Resources Bulletin*. Vol. 19, no. 6: 903-911.

- \*\* The Dakota aquifer, composed of the Dakota Sandstone and stratigraphically equivalent sandstone units of Cretaceous age, is the upper-most regional aquifer underlying the extensively developed High Plains aquifer of the midwestern United States. The concentration of dissolved solids in groundwater of the Dakota aquifer ranges from less than 500 milligrams/liter in calcium bicarbonate type water in the eastern outcrop area to more than 100,000 milligrams/liter in sodium chloride type oilfield brine in the Denver Basin to the west. Preliminary maps showing the distribution of dissolved solids confirm the complex nature of the Dakota aquifer as inferred from stratigraphic and hydraulic evidence. Extensive vertical leakage through confining layers, local recharge at the truncated eastern boundary, and a barrier to recharge along the western edge of the Denver Basin are consistent with the distribution of hydraulic head and dissolved solids.

Major, T.J., S.G. Robson, J.C. Romero, and S. Zawistowski. 1983. *Hydrogeologic Data from Parts of the Denver Basin, Colorado*. U.S. Geological Survey Open-File Report 83-274.

- \*\* This report presents hydrogeologic data collected and compiled from 1956 to 81 as part of a comprehensive hydrogeologic investigation of the Denver Basin, Colorado, by the U.S. Geological Survey in cooperation with the Colorado Department of Natural Resources, Division of Water Resources, Office of the State Engineer. The data, in tabular and graphic form, consist of records for 870 wells which include water-level data for 158 wells and water-quality analyses for 561 wells; geophysical logs from three wells, which include resistivity, self potential, and natural gamma logs; and gain-and-loss data of streamflow measured at 54 sites.

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McConaghy, J.A., P.A. Schneider Jr., and E.D. Jenkins. 1965. *Hydrology of the Denver Area, Colorado, Trip 11. Guidebook for One-Day Field Conferences, Boulder Area, Colorado.* Presented at the International Association of Quaternary Research, Seventh Congress. Lincoln, Nebraska.

- \*\*\* Surface water is the main source of water supply in the Denver area, although in places only groundwater is available, obtained from both artesian and water-table aquifers. The Quaternary surface deposits, briefly described, are not very reliable where cut through by numerous valleys, except in pockets confined by underlying shale. The stratigraphy of the Denver Basin is summarized, and viewed in Red Rocks Park area. Terrace and soil development, stream capture, and pollution of groundwater are among the topics discussed.

McCurdy, J. 1989. *Nontributary Ground Water as a Municipal Supply in the Denver Metropolitan Area.* Presented at AWRA: Water Laws and Management Conference. Tampa, Florida. September 17-22, 1989.

- \*\*\*\* Nontributary groundwater is defined as water which, when withdrawn from the ground, will not significantly deplete the surface water system within 100 years. The 6700-square-mile Denver, Colorado, groundwater basin is part of a larger structural Denver Basin that extends from central Colorado into Western Nebraska, Kansas, and Wyoming. In 1985, the Colorado legislature established a law to regulate the use of nontributary groundwater. While the right to appropriate groundwater in nontributary aquifers is tied to overlying land ownership, municipal entities are allowed to appropriate water underlying their boundaries by the implied consent of landowners. A case study conducted in the Denver area to see how nontributary groundwater could be used as a primary water source for the city is described. The environmental impact statement is presented.

McWhorter, D.B. 1984. *Specific Yield by Geophysical Logging Potential for the Denver Basin.* Technical Completion Report. Prepared for Colorado Water Resources Research Institute.

- \* Management of the groundwater resources residing in the bedrock aquifers of the Denver Basin requires estimation of the volume of water ultimately recoverable from these formations. Management of the waters in the bedrock aquifers of the Basin would be greatly expedited by a method that would permit objective estimation of specific yield on a routine basis. This report reviews the concept of specific yield, usual methods for its estimation, and the potential for use of borehole geophysical measurements as an alternate

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method for estimating specific yield. The nuclear magnetic log emerged as the most promising borehole geophysical technique. This log measures the spin-lattice relaxation time of hydrogen nuclei after being subjected to a magnetic field.

Moran and Associates, Inc. Undated report. *Environmental Constituents in the Rocky Flats Plant Area - Non-Facility Related Services Pertinent to Water Quality.*

Sources originating from non-plant site facilities may impact regional water quality. These sources include geologic materials and human activity. Geologic materials in the RFP area are known to contain sedimentary and primary uranium deposits, coal/lignites, metalliferous shales, and alluvial deposits derived from locally mineralized Precambrian metamorphic and igneous rocks. Human activity in the RFP area includes industrial wastes (other than RFP operations), natural gas storage, coal mines, landfills, railroad tracks, uranium mines and wastes, irrigation ditches, leachfields and septic tanks, agricultural run-off, and underground storage tanks. Results from groundwater sampling at upgradient locations implicate weathering of metal-sulfides, clays, organic-rich sediments, and evaporite minerals as primary source pathways.

Mudge, M.R., and R.F. Brown. 1952. *Geology and Ground Water of the Rocky Flats Area, Golden, CO.* U.S. Geological Survey Special Report for the Atomic Energy Commission.

A cursory study of the general geology and groundwater in the Rocky Flats area was made for the proposed site of a pond that is to be constructed in the southeast 1/4, northwest 1/4 section 11, T2S, R70W, Jefferson County, Colorado. The study included the Pierre Shale, Fox Hills Sandstone, Laramie Formation, and the pediment gravels. The pediment gravels and the Laramie Formation, which are present at the site, are capable of transmitting groundwater downward a short distance, possibly 100 feet, and laterally for a distance of a few feet to a few miles.

Robson, S.G., and J.C. Romero. 1981. *Geologic Structure, Hydrology, and Water Quality of the Dawson Aquifer in the Denver Basin, Colorado.* U.S. Geological Survey Hydrologic Investigations Atlas HA-643. April.

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\*\*\* Geologic structure, depth to the base, total-sandstone thickness, and potentiometric surfaces for 1958 and 1978 were mapped for the Dawson aquifer. A water-level change map from 1958 to 1978 indicates that water-levels locally declined more than 150 feet near the city of Denver. Water in the aquifer generally is a calcium bicarbonate type with dissolved-solids concentrations commonly ranging from 100 to 400 milligrams per liter and dissolved-iron concentrations as high as 85,000 micrograms per liter in a few areas.

Robson, S.G., and J.C. Romero. 1981. *Geologic Structure, Hydrology, and Water Quality of the Denver Aquifer in the Denver Basin, Colorado*. U.S. Geological Survey Hydrologic Investigation Atlas HA-646. June.

\*\*\* Geologic structure, depth to base, total conglomerate, sandstone, and siltstone thickness, and potentiometric surfaces for 1958 and 1978 were mapped for the Denver aquifer. Between 1958 and 1978, water-levels declined more than 200 feet in some areas near the city of Denver. Groundwater generally is a calcium bicarbonate or sodium bicarbonate type with dissolved-solids concentrations commonly ranging from 100 to 500 milligrams per liter and dissolved-iron concentrations as high as 6,600 micrograms per liter in a few areas.

Robson, S.G. 1987. *Bedrock Aquifers in the Denver Basin, Colorado - A Quantitative Water Resources Appraisal*. U.S. Geological Survey Professional Paper 1257 (also published in 1984 as U.S. Geological Survey Open-File Report 84-431).

\*\* Groundwater modeling techniques were used to simulate aquifer response to various pumpage estimates and groundwater development plans. It is estimated that 270 million acre-feet of recoverable groundwater is in storage in four bedrock aquifers. However, less than 0.1 percent of this volume of water is stored under confined conditions. The larger volume of water stored under unconfined conditions will be available for use only when the water levels in the confined aquifers decline below the top of the individual aquifer, allowing water table conditions to develop. Annual precipitation on the Denver Basin supplies an average of 6,900 cfs of water to the area; about 55 cfs of this recharges the bedrock aquifers. Pumpage exceeds recharge in the metropolitan area and has caused water-level declines (1958 to 78) to exceed 200 feet southeast of Denver. A quasi-three-dimensional, finite-difference model of the aquifer system was constructed and calibrated under steady-state and transient-state conditions. Steady-state calibration indicated that lateral hydraulic conductivity within the aquifers is about 100,000 times larger than vertical hydraulic conductivity between the aquifers. Transient-state calibration indicated that between 1958

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and 1978, 374,000 acre-feet of water was pumped from the aquifers, producing a 90,000-acre-foot net decrease in the volume of water in storage in the aquifers. During this time, pumpage also changed the rates of interaquifer flow, induced additional recharge, and caused capture of natural discharge. Three 1979 to 2050 pumpage estimates were made for use in simulating the effects of various groundwater development plans. Simulations, using each of these pumpage estimates, indicated that by the year 2050, large water-level declines could occur, particularly in the deeper aquifers. Maximum water-level declines of 410 feet, 1,700 feet, and 1,830 feet were produced, using the small, medium, and large pumping rates. Four plans for supplementing the Denver water supply include pumping a satellite well field, pumping a municipal well field, pumping to irrigate parks, and injecting water during periods of low demand for later use during periods of peak demand. Model simulation of these plans indicated that the satellite well field will yield twice as much water as the municipal well field but will produce larger and much more widespread water-level declines in the four aquifers.

Robson, S.G. 1983. *Alluvial and Bedrock Aquifers of the Denver Basin: Eastern Colorado's Dual Ground-Water Resource*. U.S. Geological Survey Water Supply Paper 2302.

- \*\*\*\* In the semiarid Denver Basin of eastern Colorado, large volumes of groundwater are found in alluvial and bedrock aquifers. The alluvial aquifer is recharged easily from flash floods and snowmelt runoff and readily stores and transmits the water because it consists of relatively thin deposits of gravel, sand, and clay located in the valleys of principal streams. The bedrock aquifer is recharged less easily because of its greater thickness and prevalent layers of shale, which retard the downward movement of water. Although the bedrock system contains more than 50 times as much water in storage as the alluvial aquifer, it does not store and transmit water as readily as the latter. Because of these and other factors, including legal and economic constraints and water quality conditions, the alluvial aquifer is used primarily as a source of irrigation supply, which is the largest water use in the area.

Robson, S.G., J.C. Romero, and S. Zawistowski. 1981. *Geologic Structure, Hydrology, and Water Quality of the Arapahoe Aquifer in the Denver Basin, Colorado*. U.S. Geological Survey Hydrologic Investigations Atlas HA-647. December.

- \*\*\* Geologic structure, depth to base, total conglomerate, sandstone, and siltstone thickness, and potentiometric surfaces of the Arapahoe aquifer for 1958 and 1978 were mapped. Between 1958 and 1978, water-level declines in the Arapahoe aquifer exceeded 200 feet in a 135-square-mile area southeast of Denver. The Arapahoe aquifer groundwater generally is of

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the sodium bicarbonate type with dissolved-solids concentrations commonly ranging from 200 to 1,000 milligrams per liter. Concentrations of dissolved sulfate in excess of 250 milligrams per liter occur in a 350-square-mile area along the northwest margin of the aquifer.

Robson, S.G., A. Wacinski, S. Zawistowski, and J.C. Romero. 1981. *Geologic Structure, Hydrology, and Water Quality of the Laramie-Fox Hills Aquifer in the Denver Basin, Colorado*. U.S. Geological Survey Hydrologic Investigations Atlas HA-650.

- \*\* The Laramie-Fox Hills aquifer underlies an area of about 6,700 square miles in east-central Colorado and is an important water supply for many residents in the area. Population increases have produced increasing demands for groundwater and have led to significant water-level declines in parts of the aquifer. Results of this study, which was undertaken to better define the water-supply potential of the aquifer, indicate that the aquifer consists of interbedded sandstone, siltstone, and shale at depths of as much as 3,200 feet. The water-yielding sandstone and siltstone beds have a total thickness of more than 200 feet in some areas. The 1978 potentiometric-surface map indicates that groundwater moves from the south-central part of the aquifer toward the margins of the aquifer where most of the water discharges to streams and alluvial aquifers. Some groundwater recharge occurs as downward movement of water from the overlying Arapahoe aquifer. Water-level declines between 1958 and 1978 exceeded 200 feet in an 80-square-mile area near Brighton, while in other parts of the aquifer, only moderate changes have occurred. Water in the aquifer is generally of a sodium bicarbonate type with dissolved-solids concentrations commonly ranging from 400 to 1,200 milligrams per liter.

Robson, S.G., and E.R. Banta. 1987. *Geology and Hydrology of Deep Bedrock Aquifers in Eastern Colorado*. U.S. Geological Survey Water Resources Investigations Report 85-4240.

- \*\* Deep bedrock aquifers are present in rocks of Cretaceous through Pennsylvanian age in eastern Colorado. These aquifers are the Laramie-Fox Hills (the uppermost aquifer studied), Fort Hays-Codell, Dakota-Cheyenne, Entrada-Dockum, Lyons, and Fountain. Structural mapping indicates that the aquifers are 2,000 to 9,000 feet below land surface in most of eastern Colorado but outcrop in local areas in a narrow band along the Front Range of the Rocky Mountains. Recharge primarily occurs at outcrops and produces a northerly or easterly groundwater flow to discharge areas along the South Platte or Arkansas Rivers. Deep aquifers also discharge by underflow to Kansas and Nebraska. Some water-yielding strata in the Dakota-Cheyenne aquifer are not in hydraulic connection with the

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aquifer, and abnormal fluid pressures, trapped hydrocarbons, and high dissolved-solids concentrations are found in these strata. Temperature and dissolved-solids mapping indicate water temperatures of 100°F to 210°F in northeastern Colorado and a zone of relatively fresh water extending through a 7,000- square-mile area of the Dakota-Cheyenne aquifer in southeastern Colorado. Water levels in the Laramie-Fox Hills aquifer continue to decline as much as 12 feet per year in local areas near Denver.

Rockwell International. 1982. *Annual Environmental Monitoring Report, January - December 1981, Rocky Flats Plant, Golden, CO.*

This report documents the environmental surveillance program conducted at the RFP during 1981. Groundwater from 56 monitoring locations was collected at regular intervals and tested for select radionuclides. Monitoring wells are generally located around the plant perimeter, upgradient and downgradient of various evaporation ponds, near drainage areas, and near spray irrigation sites. Tests indicate that very low concentrations of radionuclides exist in groundwater at RFP. Some radionuclides at these concentrations may be naturally occurring and not related to plant operations. A map shows exact monitoring locations, and laboratory results support conclusions.

Rockwell International. 1983. *Removal of Nitrates from Groundwater by Reverse Osmosis, Rocky Flats Plant, Golden, CO.* Prepared for the U.S. Department of Energy. August.

\* A hybrid process is presented permitting the reduction of nitrate content of groundwater to the allowable limit (less than or equal to 50 ppm) while simultaneously reducing the total salt content and the discharge volume of the concentrated brine. Design data were determined for a pilot plant (18 cubic meters/hour potable water) and for a large-scale plant (360 cubic meters/hour). The specific potable water production costs to be expected for the discussed concepts are provided.

Rockwell International. 1984. *Annual Environmental Monitoring Report, January - December 1983, Rocky Flats Plant, Golden, CO.*

This report documents the environmental surveillance program conducted at RFP during 1983. Groundwater from 56 monitoring locations was collected quarterly and tested for select radionuclides. Monitoring wells are generally located around the plant perimeter,

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upgradient and downgradient of evaporation and holding ponds, and near drainage areas, underground tanks, burial sites, a landfill, and spray irrigation sites. Tests indicate that low concentrations of radionuclides exist in groundwater at RFP. Radionuclides at these concentrations may be naturally occurring and not related to plant operations. A site map shows exact monitoring locations, and laboratory results support conclusions.

Rockwell International. 1985. *Annual Environmental Monitoring Report, January-December 1984, Rocky Flats Plant, Golden, CO*. Prepared for the U.S. Department of Energy. March 25.

\* This report documents the environmental surveillance program at RFP, as conducted by the Environmental Analysis and Control Section of the Environmental and Occupational Health Branch. The report includes an evaluation of plant compliance with all appropriate guides, limits, and standards. Comparisons with appropriate guides, limits, and standards and with background levels from natural or other non-plant sources, provide a basis for concluding that no adverse environmental effects were attributable to the operation of RFP during 1984.

Rockwell International. 1986. *Annual Environmental Monitoring Report, January - December 1985, Rocky Flats Plant, Golden, CO*.

This report documents the environmental surveillance program conducted at RFP during 1985. Groundwater was collected from 95 monitoring wells within and around RFP and tested for volatile organic compounds (VOCs), metals, radionuclides, and other water-quality indicator parameters. A single round of groundwater sampling was conducted because of time constraints. Extensive hydrologic investigations conducted during 1986 resulted in characterization of the site-specific hydrogeologic setting and added numerous monitoring wells to the existing monitoring well network. A complete report of the 1986 investigations is provided in the RFP RCRA Part B Permit Application. Tests indicate that the groundwater contains volatile organics, elevated total strontium, and some radionuclides. A continuing groundwater monitoring program has been planned for subsequent years to delineate the extent and magnitude of groundwater contamination at high-priority sites. A map showing exact monitoring locations, and laboratory results is presented.

Rockwell International, Hydro-Search, and Weston. 1986. *Geological and Hydrological Data Summary, Rocky Flats Plant, Golden, CO*. July.

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A summary of existing geologic, hydrologic, and water-quality data for RFP was compiled from all previous investigations. Hydrogeologic data contained within this document include monitor well construction/completion details, hydrogeologic setting at RFP, groundwater chemistry characteristics and classifications, electromagnetic survey results, and soil-gas investigation results.

Rockwell International. 1986. *Resource Conservation and Recovery Act Part B - Operating Permit Application for U.S. Department of Energy - Rocky Flats Plant Hazardous and Radioactive Mixed Wastes (CO7890010526)*, Vol. VI. November 28.

A discussion of groundwater protection is included in the Part B RCRA operating permit application (as Section E) and includes a description of the hydrogeologic setting and results of the Phase I investigations available to-date. Tables and figures present historical groundwater monitoring data. An electromagnetic survey conducted at the site indicated several areas of high conductivity (i.e., high total dissolved solids). Similarly, results of a soil-gas survey provide insight as to the potential for groundwater contamination. Results of drawdown-recovery tests are presented indicating hydraulic conductivities. Closure plans for three RCRA units, including groundwater monitoring programs, have been developed. These plans stipulate detection monitoring at specific points of compliance. A summary of the constituents detected in groundwater allows for the evaluation of contaminant plumes and a characterization of the potential sources of contamination. Based on chemical data collected, the underlying aquifer does not appear to be impacted by plant operations. Plates containing cross-sections, well locations, and the potentiometric surface are included. Several appendices present data on groundwater monitoring, including borehole logs, hydrologic test data, and chemical data.

Rockwell International. 1987. *Remedial Investigation Report, 903 Pad, Mound and East Trenches Areas, Rocky Flats Plant, Golden, CO*. December 31.

This investigation was conducted to verify the existence and location of the waste disposal sites, to characterize the sites, evaluate the nature and extent of contamination, and develop data needs for feasibility studies of remedial alternatives. The investigation included a groundwater sampling program to further characterize the hydrogeological and hydrogeochemical setting specific to the areas of concern. Bedrock highs in the East Trenches Area divert groundwater to the northeast and toward the north and south edges of the Rocky Flats terrace. Groundwater that flows toward the terrace edges emerges as

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seeps and ultimately discharges in creeks. Groundwater from the areas of concern does not carry contaminants to the property boundary. Therefore, there is no immediate public health threat. In each area of concern the groundwater is contaminated with various chlorinated solvents which appear to be released from multiple sources including the drum storage site, reactive metal destruction site, and Trenches T-2, T-3, and T-5 through T-9. Studies indicate that volatilization, adsorption, or dilution reduces volatile organic compound (VOC) concentrations to non-detectable levels as alluvial groundwater migrates eastward and toward drainages. Bedrock groundwater in the 903 Pad area is contaminated with VOCs. Further investigations are required to delineate the downgradient extent of contamination. Low concentrations and sporadic detections of radionuclides in the areas of concern guide the tentative conclusions that radionuclide contamination of groundwater does not exist. Further sampling and analysis are required for confirmation.

Rockwell International. 1988. *Environmental Assessment Report for High-Priority Sites (881 Hillside Area), Rocky Flats Plant, Golden, CO.* December 23.

The document contains information supporting the proposed remedial action at the 881 Hillside Area. Groundwater in this area is contaminated with volatile organic compounds. The proposed action includes installation of a pumping well, drain system, re-injection trench, and collection tanks. It also includes a treatment facility for the collection, treatment, and release of groundwater. If no remedial action is taken, additional impacts to surface water and groundwater could result from continued release of contamination. The implementation of this system will reduce contaminant concentrations in groundwater and prevent possible offsite contamination via groundwater in the future.

Rockwell International. 1988. *Ground-Water Monitoring of Regulated Units, Rocky Flats Plant, Golden, CO.* March 31.

In accordance with regulations governing the interim status of the three RCRA-regulated units (Solar Evaporation Ponds [SEPs], West Spray Field [WSF], and Present Landfill [PL]) undergoing closure at RFP, groundwater monitoring programs have been established for these sites. During 1986, a comprehensive program that included site characterization,

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remedial investigations, feasibility studies, and corrective action was implemented at RFP. Additional wells were installed in 1986 to characterize and delineate groundwater plume(s) at the SEPs and to aid in site characterization at the WSF and PL. Figures presented illustrate a general easterly groundwater flow direction for these sites. Although not summarized, groundwater quality data sheets are provided for samples collected during 1986 and 1987. The upcoming (July 1988 completion date expected) respective closure plans for these three units are referenced for in-depth discussions of the data.

Rockwell International. 1988. *Present Landfill Closure Plan*. Prepared for the U.S. Department of Energy. July 1.

In accordance with the Colorado Code of Regulations, a closure plan for the RFP Present Landfill was developed. Prior to considering closure activities, a detailed history of the Present Landfill, including wastes accepted (presented in tables), dates of operation, construction history, and current landfill operations are evaluated. Closure activities include analysis of the north spray field area, grading, placement of a cap and subsequent vegetative cover, maintenance of the closed area, evaluation of existing groundwater collection system, and installation of a groundwater collection system. Flow diagrams and figures summarize the closure activities proposed. Engineered drawings of landfill renovations and landfill features, as well as volume and engineering calculations (i.e., final cover and slope analysis) are included as appendices. Results of a soil-gas survey conducted at the landfill indicate that minor amounts, if any, of methane and hydrogen sulfide are produced. However, a passive gas collection and venting system is proposed to address potential future generation of landfill gases. Certification requirements and an anticipated closure schedule are included.

Rockwell International. 1988. *Remedial Investigation Report for High Priority Sites (881 Hillside Area)*. Prepared for the U.S. Department of Energy. March 1.

The 881 Hillside Area, which consists of 12 solid waste management units (SWMUs), was identified during a 1986 characterization of the RFP facility as a high-priority site and one of four areas considered to be significant sources of environmental contamination. A remedial investigation (RI) was conducted at the 881 Hillside Area to investigate the locations of alleged waste disposal sites, characterize the sites, and evaluate the nature and extent of contamination, including the high concentrations of volatile organic compounds (VOCs) detected in groundwater. In addition to various types of sampling and surveys conducted as part of the RI, monitoring wells were installed and groundwater samples were

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collected. Potentiometric surface and saturated thickness maps present information on site hydrogeology. Borehole logs and monitoring well construction details also provide information on the site characteristics. Analytical data indicate that low levels of VOCs were detected in the general vicinity of SWMUs 103, 106, and 107, and much higher levels were detected at SWMU 119.1. The extent of groundwater contamination appears to be limited by clayey soils of low hydraulic conductivity. The clayey soils contain discontinuous lenses of more permeable materials resulting in a small quantity of groundwater flow. Shallow groundwater beneath the 881 Hillside contains above-background concentrations of metals, radionuclides, and total dissolved solids (TDS). The only constituents present above background levels in groundwater downgradient of the 881 Hillside were TDS and strontium at very low concentrations. Bedrock groundwater quality does not appear to be adversely impacted.

Rockwell International. 1988. *Resource Conservation and Recovery Act Post-Closure Care Permit Application for U.S. DOE - Rocky Flats Plant Hazardous and Radioactive Mixed Wastes (CO7890010526)*. October 5.

A summary of groundwater monitoring and protection plans is presented that details the interim-status and post-closure activities for groundwater associated with the Present Landfill, Original Process Waste Line, West Spray Field, and Solar Evaporation Ponds. Results of the interim-status monitoring are presented with plans for continued interim-status monitoring. A description of the uppermost aquifer, points of compliance, contaminant plumes, monitoring requirements, and monitoring programs presents a summary of the hydrology and geochemistry of groundwater beneath these sites. Numerous figures, plates, and tables present groundwater data. Closure plans covered under this permit application are included as appendices.

Rockwell International. 1989. *Rocky Flats Plant Site Environmental Report for 1988*. Prepared for the U.S. Department of Energy.

This report documents the environmental surveillance program at RFP during 1988. Groundwater was collected from 159 monitoring wells within and around RFP and analyzed for volatile organic compounds (VOCs), metals, radionuclides, and other water-quality indicator parameters. Results indicate that groundwater has been impacted locally in areas of past and present plant operations. These areas include the Solar Ponds; West Spray Field; 881 Hillside; 903 Pad, Mound, and East Trenches; and Present Landfill areas.

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Contaminants include VOCs and elevated levels of nitrate, sulfate, bicarbonate, metals, and radionuclides.

Rockwell International. 1988. *Solar Evaporation Ponds Closure Plan, Rocky Flats Plant, Golden, CO*. Prepared for the U.S. Department of Energy. July 1.

This plan describes the work to be implemented in order to comply with all regulations for closure of the Solar Evaporation Ponds as a RCRA-regulated unit. This plan addresses the contaminated groundwater problem and proposes a system to collect, remove, and treat affected groundwater. Collection and removal of groundwater will occur through a French drain, and an interceptor drain. The collected water will be treated to reduce concentrations of contaminants. Groundwater monitoring wells installed in 1986 and 1987 to assess the extent of groundwater contamination resulting from pond leakage will be sampled and monitored to meet the closure groundwater monitoring requirements.

Rockwell International. 1989. *1988 Annual RCRA Ground-Water Monitoring Report For Regulated Units at Rocky Flats Plant, Golden, CO*. March 1.

For the purpose of determining the impact of waste management activities at three RCRA-regulated units at RFP (the Solar Evaporation Ponds [SEPs], West Spray Field [WSF], and Present Landfill [PL]) on groundwater, 1988 groundwater data for each unit are evaluated with respect to the site background data. Upon evaluating the results, the current groundwater monitoring program is assessed for effectiveness, and recommendations are made for future monitoring. Maps, analytical data, and calculations support conclusions drawn regarding the nature and extent of groundwater contamination, groundwater flow direction and chemistry, and contaminant migration rates. Results of the 1988 groundwater monitoring program indicate that major contamination constituents in groundwater at the SEPs include nitrate and dissolved uranium. The main contamination constituent at the WSF is nitrate. The major contamination constituents at the PL include major ions, manganese, and iron.

Rockwell International. 1989. *Background Hydrogeochemical Characterization and Monitoring Plan, Rocky Flats Plant, Golden, CO*. January.

This characterization and monitoring plan was developed to aid in evaluating potential groundwater contamination associated with the RCRA-regulated units at RFP, as well as

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interpreting remedial investigation analytical results for the CERCLA sites. The chemistry of groundwater from areas unimpacted by plant operations will be used, by comparison, to evaluate the extent of adverse impacts to groundwater on the plant site. Methodologies proposed to characterize background water chemistry and detect potential impacts are presented.

Rocky Mountain Universities Consortium. 1992. *Final Report Water Quality and Toxicity Literature Review*. Prepared for EG&G Rocky Flats, Inc. November.

This project was undertaken to assemble sensitivity ranges and toxicity limits for selected aquatic species to organics, metals, and pesticides, and to conduct a literature search. The literature search documents Front Range water quality and assembles information on Jefferson County highway maintenance and operations procedures that might affect water quality. Findings of the literature review concluded that groundwater data were not complete because of nonroutine sampling occurrences. Groundwater samples were collected from several wells by the U.S. Geological Survey (USGS) and by the Jefferson County Health Department (JCHD). Water-quality data were obtained by the USGS from well water in the general vicinity of Rocky Flats and Coal Creek Canyon. Data include water-quality analyses of well water sampled during 1973 and 1975 and results of total uranium, <sup>226</sup>radium, and <sup>222</sup>radon activity measurements on well water collected in 1991 and 1992. The results of the JCHD Groundwater Monitoring Program are presented. This program was implemented to obtain groundwater quality data, to evaluate the effect of septic systems on domestic groundwater supplies, and to protect groundwater resources in Jefferson County.

Romero, J.C. 1976. *Ground Water Resources of the Bedrock Aquifers of the Denver Basin, Colorado*. Colorado Department of Natural Resources, Denver Division of Water Resources, Planning, and Investigations.

\*\* The bedrock aquifers of the Denver Basin contain vast quantities of groundwater suitable, in most localities, for all beneficial purposes. The major problems that will confront both administrators and users of this groundwater include those associated with declining water levels and deterioration of water quality. Areas in which current water-level declines are rapid enough to cause concern are the South Platte River corridor, the Strasburg-Byers-Deer Trail area, and parts of metropolitan Denver. Water-quality problems of the Denver Basin's bedrock aquifers are confined predominantly to the Laramie Formation and Laramie-Fox Hills aquifer. Water from these units is locally known to contain troublesome amounts of hydrogen sulfide, methane, iron, fluoride, and sodium. Many of these problems can

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probably be eliminated by avoiding multi-aquifer completions, particularly in the case of mixing Laramie-Fox Hill aquifer water with Dawson Group water. Successful management of the Denver Basin bedrock aquifers will require the collection and utilization of additional data. The importance of additional electric logs, geologic sample logs, and aquifer test data cannot be over-emphasized. Also of major importance are water-quality testing, an observation-well network, and accurate measurements of water withdrawn from the aquifer. If managed with caution, the Denver Basin can supply the water needs of several generations.

Schenk-Tarasuk, J.A. 1990. "RIVINT; Computer Program for Surface Water/Ground-Water Interactions and its Application to the Denver Basin, Colorado." Masters Thesis, Colorado School of Mines.

\*\*\* RIVINT (RIVER INteractions) is a computer code that simulates surface water and groundwater interactions. RIVINT has been developed for use with the USGS three-dimensional finite difference groundwater flow code (MODFLOW) and is used in place of the original river package in the MODFLOW programs. Users may model river reaches with or without alluvium. Seepage between a river and underlying aquifer is calculated and used in the MODFLOW code as part of the calculation of head in a grid cell. The form of the equation for seepage between a river and an aquifer is dependent on the nature of hydraulic conditions that exist between the river and the aquifer. The user has the option of including silt layer parameters to represent a silt layer in the riverbed. The form of the equation for seepage between alluvium and aquifer is dependent on the nature of hydraulic conditions that exist between the alluvium and underlying aquifer if alluvium is modeled explicitly using the river package. River discharge is calculated by summing flows into and out of the river in a mass balance equation. Using Manning's equation for flow in an open channel, river depth and stage is calculated. If alluvium is explicitly modeled, net flow rate in the alluvial reach is calculated as the difference between inflows to and outflows from the reach. Change in head of the alluvium is equal to the net flow rate into or out of the alluvium, multiplied by the time- step length, and divided by the specific yield and area of seepage. Output for reaches containing only rivers includes location of the reach in the groundwater grid, river discharge, river stage, and seepage rate between the river and grid cell. Output for reaches simulating river and alluvium includes reach location, head in the alluvium, seepage rate between alluvium and bedrock, river discharge, river stage, and seepage rate between the river and alluvium. RIVINT is used to model rivers and their alluvium in the Denver Basin of Colorado to assess how rivers are affected by pumping of groundwater in bedrock aquifers.

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Schneider, P.A. Jr. 1980. *Water-Supply Assessment of the Laramie-Fox Hills Aquifer in Parts of Adams, Boulder, Jefferson, and Weld Counties, Colorado*. U.S. Geological Survey Open-File Report 80-327.

Groundwater in the Laramie-Fox Hills aquifer is a potential source of supplemental municipal water supplies for the communities of Erie, Lafayette, Louisville, and Superior in Colorado. The present water supplies for these communities are not always adequate to meet current demands. The U.S. Geological Survey made a water-supply assessment of the Laramie-Fox Hills aquifer for the U.S. Bureau of Reclamation which is investigating and evaluating alternative sources of water for the communities. Recharge to the aquifer is mostly in the western and southwestern parts of the study area. Groundwater movement is generally from the southwest to northeast. Groundwater discharge in the study area is primarily by pumping wells. Since 1961, this pumping has caused water-level declines of about 250 to 300 feet from Broomfield to east of Erie, Colorado. Generally, water levels in other parts of the area have remained the same. The aggregate sand and aquifer thickness determined from well logs ranges from 42 to 360 feet and the mean thickness is 229 feet. The volume of groundwater in storage in the study area is about 5 million acre-feet. Reported yields from 93 wells ranged from 1 to 90 gallons per minute and averaged 22 gallons per minute. Well yields tended to be larger in the areas where aggregate sand thickness is the greatest. The water changes from a sodium calcium bicarbonate type to a sodium calcium sulfate type as it moves through the aquifer away from the recharge areas. The maximum limit established by the U.S. Environmental Protection Agency for nitrite plus nitrate in public water supplies was exceeded in water from three wells, the maximum limit for fluoride was exceeded in water from two wells, and the maximum limit for selenium was exceeded in water from three wells. (Abstract from report.)

Snow, D.T. 1968. "Hydraulic Character of Fractured Metamorphic Rocks of the Front Range and Implications to the Rocky Mountain Arsenal Well." *Colorado School of Mines Quarterly*. Vol. 63, no. 1.

\*\* Hydraulic and geometrical properties of fractured metamorphic rocks of the Front Range of Colorado are determined from damsite pressure-injection tests and records of domestic water wells. Because the same rocks beneath the Denver Basin comprise the reservoir into which fluid wastes have been injected at the Rocky Mountain Arsenal well, the Front Range properties are applicable to studies of the arsenal well-injection performance and the possible earthquake response. Fracture permeability may be of like origin in both cases: faulting, weathering, and erosional stress release beneath a surface of erosion. At damsites

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in the Front Range metamorphic rocks, fracture spacing is about 5 to 10 feet near the ground surface, increasing to about 15 to 35 feet at the 200-foot level. Water wells intercept even fewer significant fractures. Openings close from approximately 200 microns to 70 microns between the near-surface and the 200-foot depth, and porosities decrease from approximately 0.04 percent to 0.001 percent. The logarithm of permeability decreases linearly with the logarithm of depth. The fractured aquifer is a thin skin draped over the terrain. Test data suggest that the aquifer is bounded by vanishing permeability at about 200 feet, though open fault zones may extend to greater depths. Different lithologic units have different transmissibilities. These exceed the transmissibilities deducted from arsenal well flow, so the pre-Pennsylvanian soils and sediments resting on the gneiss at the well site may effectively confine flow to the fractured basement.

S.S. Papadopoulos and Associates, Inc. 1987. *Ground-Water Modeling of Impacts of Proposed Spray Irrigation, Rocky Flats Plant, Golden, CO*. Prepared for Rockwell International. December.

The purpose of this study was to estimate the impacts to the water table and groundwater flow directions from spray irrigating 80 million gallons per year of tertiary treated sewage effluent. Two proposed locations were evaluated. The groundwater assessment included a groundwater flow model based on an analytical technique developed by M.S. Hantush that was used to make quantitative analyses for each site. The analytical solution analyzes the growth of a groundwater mound in an unconfined aquifer due to surface recharge from a circular basin by evaluating the changes in hydraulic head over time. Field data collected in 1986 (depth to water, depth to bedrock) were entered into the model to evaluate alternative spray irrigation scenarios. A total of 12 and 9 different scenarios were evaluated for the two proposed spray irrigation areas. A recharge rate of 45 million gallons per year was used. In all scenarios, based on this recharge rate, the water table would intercept land surface and overland flow would occur where recharge lasts longer than three years. The study also concluded that the maximum amount of water that could be recharged, per spray area, without the occurrence of overland flow is 15 to 20 million gallons per year. The study recommended that alternatives to spray irrigation be investigated, or that only a fraction of the proposed 80 million gallons of waste water be spray irrigated. Various figures of water-table rise generated by the computer model are presented that support the conclusions.

U.S. Department of Energy. 1980. *Annual Environmental Monitoring Report, Rocky Flats Plant, Golden, CO, January - December 1979*. April 10.

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This report documents the environmental surveillance program conducted during 1979 at RFP. Groundwater samples from 42 hydrologic test sites within RFP were collected at regular intervals and tested for select radionuclides during 1979. Test sites are generally located around plant perimeter fences and near various evaporation ponds. Tests indicate that very low concentrations of radionuclides exist in groundwater at RFP. Some concentrations of radionuclides may be naturally occurring and not the result of plant operations. A map shows exact monitoring locations, and laboratory test results support conclusions.

U.S. Department of Energy. 1980. *Environmental Impact Statement, Rocky Flats Plant Site, Golden, CO.*

The National Environmental Policy Act of 1969 requires agencies of the federal government to prepare environmental impact statements regarding any major federal action significantly affecting the quality of the human environment. Information on groundwater is very general and includes statements regarding sitewide hydrologic conditions. An explanation of the sitewide hydrologic system is included with details describing groundwater occurrence, recharge, discharge, and flow characteristics for the separate hydrostratigraphic units. Water quality depends largely on the water quality recharging the aquifers, and it is unlikely that groundwater quality in lower hydrostratigraphic units is affected by the plant operations. The uppermost hydrostratigraphic unit is the most likely to be impacted by plant operations. This hydrostratigraphic unit does not supply water to any offsite wells. Discharge into surface water from the uppermost hydrostratigraphic unit could directly or indirectly affect the water quality of the downstream water supply for a considerable distance and for a considerable length of time. Groundwater sampling occurs every five months at onsite and offsite locations. Data from monitoring is used to determine the movement of chemical and radioactive materials into the groundwater-bearing strata. The monitoring holes are located near the Solar Ponds, downgradient of the holding ponds, and east of the plant site.

U.S. Department of Energy. 1989. *Groundwater Assessment Plan, Rocky Flats Plant, Golden, CO.* September.

This plan reviews the current (1989) interim-status groundwater monitoring program at RFP to ensure long-term quality and consistency of the program and compliance with the Colorado Code of Regulations. Major components in the program include investigations to determine background groundwater quality, groundwater contamination, groundwater migration rates, and concentrations of contaminants in groundwater. An extensive review

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of the hydrologic setting was conducted in conjunction with the design of this program. The areas included in the program are the Solar Evaporation Ponds (SEPs), Present Landfill (PL), and West Spray Field (WSF). Tables, lists, and maps detail the monitoring well network and the required analytical parameters.

U.S. Department of Energy. 1990. *Environmental Assessment for 881 Hillside (High Priority Sites) Interim Remedial Action, Rocky Flats Plant, Golden, CO.* January.

Although discontinued in 1972, portions of the 881 Hillside were used for waste disposal and storage. These sites included oil sludge pits, chemical burial and solvent-drum storage sites, and liquid disposal sites. These practices resulted in impacts to soil and alluvial groundwater in this vicinity with volatile organic compounds, metals, major ions, and uranium now present above background concentrations. In order to prevent the release and migration of impacted groundwater from this area, as well as to reduce existing contamination within the groundwater, the U.S. Department of Energy proposed to collect impacted groundwater from identified sources, install a French drain, treat groundwater using ultraviolet (UV)/peroxidation and ion exchange techniques, and discharge the treated effluent at the surface. An Environmental Assessment was prepared to assess the environmental impacts and risks to exposed populations resulting from the proposed and alternative actions. Information evaluated included risk assessment criteria. Conclusions indicate that the proposed action of treating groundwater with UV/peroxidation and ion exchange was preferable over the other alternatives in containing, removing, and destroying the contaminants of concern.

U.S. Department of Energy. 1991. *Final Historical Information Summary and Preliminary Health Risk Assessment, Operable Unit No. 3 - IHSSs 200-202, Rocky Flats Plant.* Prepared for the U.S. Department of Energy. June.

Sediments in Great Western Reservoir, Standley Lake, and Mower Reservoir (Individual Hazardous Substance Sites [IHSSs] 200, 201, and 202, respectively) contain low levels of plutonium as a result of past activities at RFP, located upgradient of these sites. In accordance with the Interagency Agreement for RFP, possible groundwater sources, among others, were identified as potentially impacting these IHSSs. The primary objectives of this report are (1) to present all available data describing contamination within the reservoirs and tributaries of the reservoirs, including groundwater, and (2) to provide a human health risk assessment associated with a no-action remedial alternative. A summary of the hydrogeologic conditions near Great Western Reservoir is included. A qualitative human

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health risk assessment was conducted as it became apparent that the available data would not meet the current quality control standards necessary to support a quantitative risk assessment. A "generic" risk assessment calculation is presented that generates risk values based on hypothetical plutonium levels in reservoir water and sediment. The study concluded that plutonium adsorbed to clay-rich reservoir sediments is effectively immobilized. Water quality in these lakes has not been measurably impacted by plutonium in the sediments. The most significant exposure pathway for the reservoir is entrainment and dispersion of exposed sediments.

U.S. Department of Energy. 1991. *Final Past Remedy Report, Operable Unit No. 3-IHSS 199, Rocky Flats Plant, Golden, CO.* April.

A review of the local hydrogeologic system reveals that groundwater may be a secondary source of plutonium contamination to IHSS 199. Quantified results from investigations of soil and water indicate that plutonium would not readily migrate horizontally or vertically in groundwater and that groundwater is not a likely pathway for dissolved plutonium migration at the site. Further investigations may be warranted to study the transport of plutonium bound to colloidal particles in groundwater.

U.S. Department of Energy. 1992. *Final No Further Action Justification Document, Rocky Flats Plant, Low Priority Sites (Operable Unit 16), Golden, CO.* July.

This document for Operable Unit No. 16 (OU 16) was prepared as part of the site characterization, remedial investigation, feasibility studies, and remedial/corrective actions in progress at RFP. OU 16 contains seven individual hazardous substance sites (IHSSs 185, 192, 193, 194, 195, 196, and 197) that either have undergone previous response actions or are associated with natural environmental processes eliminating the need for further action. Each IHSS was evaluated for risks to human health and the environment using a site conceptual model to evaluate the exposure pathways, including groundwater as a transport medium or pathway, by which potential receptors may be exposed to contaminants. A summary of the hydrogeology of OU 16 is presented and is accompanied by a potentiometric surface map. Groundwater quality data are presented as an appendix. This study concluded that further action is not justified at six of the seven IHSSs because past response actions and/or natural attenuation processes have eliminated the source or exposure pathways. Further action is warranted only at IHSS 196, the Water Treatment Plant Backwash Pond.

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U.S. Department of Energy. 1992. *Phase I RFI/RI Work Plan, Rocky Flats Plant, Solar Evaporation Ponds (Operable Unit No. 4), Golden, CO.* January.

The broad goals of the Phase I investigations at the Solar Evaporation Ponds (SEPs) include characterization of the physical features of the sources at the site and definition of the contaminant sources within Operable Unit No. 4 (OU 4). Site-specific objectives and data needs have been identified and a field sampling plan has been designed. The Phase I investigation at the SEPs includes limited hydrogeologic studies. The main focus is on source materials and soils. However, a comprehensive understanding of site-specific (SEP) hydrogeologic background characteristics and knowledge of previous groundwater investigations conducted at the SEPs are essential in order to develop an effective and thorough Phase I investigation. Groundwater is considered to be a potential contaminant pathway to the biotic environments located around seeps. Groundwater investigations during the OU 4 Phase I RFI/RI are limited to piezometer installation to provide information on the water-table configuration along the OU 4 boundary.

U.S. Department of Energy. 1992. *Well Abandonment and Replacement Program, Rocky Flats Plant, Golden, CO - Final Report.* December.

Improperly constructed or damaged monitoring wells and piezometers were recently abandoned to mitigate the potential for contaminant migration and to ensure the integrity of the groundwater monitoring data obtained from these wells/piezometers. Forty-six wells were abandoned and 7 replacement wells were installed from January through September 1992. Criteria established in 1990 for well abandonment were used in the January 1991 Draft Well Evaluation Report to identify wells/piezometers appropriate for abandonment. Technical procedures for well abandonment and replacement are presented, including geophysical logging procedures. Data obtained during abandonment and replacement activities are summarized in tables, a figure, and appendices.

U.S. Department of Energy. 1993. *Final Ground Water Assessment Plan, Rocky Flats Plant, Golden, CO.* February.

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As governed by the Interagency Agreement, and in accordance with a Colorado Department of Health Compliance Order, a groundwater assessment plan was developed describing procedures for conducting the RCRA, interim groundwater-monitoring and data-evaluation program for the three RCRA-regulated units at RFP. These units include the Present Landfill (PL), West Spray Field (WSF), and Solar Evaporation Ponds (SEPs). Site-specific data for each of the regulated units provide information on historical uses, geology, hydrogeologic conditions, and present and proposed groundwater monitoring activities. The 1990 groundwater monitoring results indicate that contaminants detected above background in the WSF groundwater include metals, anions (fluoride, nitrate/nitrite, phosphate, silica, sulfate, and total suspended solids), methylene chloride, and radionuclides. Analytes present at elevated concentrations in groundwater underlying the PL include inorganics (nitrate/nitrite, bicarbonate, chloride, sulfate, total dissolved solids, calcium, magnesium, and sodium), metals, radionuclides, and volatile organic compounds (VOCs). Contaminants detected above site background concentrations in groundwater beneath the SEPs include total dissolved solids, metals, VOCs, radionuclides, and nitrate/nitrite. General assessment plan information includes procedures for monitoring groundwater at the site, evaluating data at points of compliance, and assessing groundwater flow and the extent of the contamination. A summary of background groundwater quality data and a description of the statistical methodologies used in evaluating groundwater results is also included.

U.S. Environmental Protection Agency Hazardous Waste Ground-Water Task Force. 1988. *Ground-Water Monitoring Evaluation, U.S. DOE, Rocky Flats Plant, Golden, CO.* August 3.

The procedures for groundwater sampling and analysis, monitoring well location and construction, sample collection and handling, and sample analysis and data quality evaluation were critically reviewed and were found to be generally unsatisfactory and, at times, out of compliance. The groundwater monitoring program proposed for RCRA permitting was found to be inappropriate as a result of improper well placement, incorrect proposed program type, and deficiencies in proposed monitoring parameters. The monitoring evaluation included a sample and data collection task. These data were evaluated together with existing data. The investigation concluded that many deficiencies still exist in the RFP groundwater monitoring program. Maps, lists, data results, and diagrams support and aid findings.

Van Slyke, G., J. Romero, and A. Wacinski. 1986. *Aquifer Data from Geophysical Logs, Denver Basin, Colorado.* U.S. Geological Survey Basic Data Report 1.

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This report was generated to assist in the formulation of rules and regulations on the withdrawal of groundwater from the Denver Basin aquifers. The Denver Basin covers 6,700 square miles and contains four aquifers. The aquifers include the Dawson, Denver, Arapahoe, and Laramie-Fox Hills. Data have been interpreted for over 2,400 geophysical logs of oil, gas, and water wells in the Denver Basin. Log data include well location, surface elevation, elevation of tops and bases of aquifers, and total thicknesses of sandstones and siltstones.

W.W. Wheeler & Associates, Inc. 1972. *Report on Hydrologic Investigation - Rocky Flats*. Prepared for C.F. Braun & Co. September.

In preparation for a new plutonium recovery facility to be constructed at RFP, an environmental study was undertaken to evaluate concerns relating to site hydrology and storm events. A brief summary of the site geology facilitates an understanding of the potential pathways taken by contaminated water infiltrating the ground surface. Precipitation will most likely infiltrate through the relatively permeable Rocky Flats Alluvium and remain perched atop the underlying Laramie Formation bedrock. A percentage of the infiltrated precipitation will then eventually flow offsite to the Great Western Reservoir. A portion of the infiltrated water will percolate slowly through the upper portion of the bedrock and become incorporated into the existing water table. Eventually this water will intercept wells located to the east. Hydrographs and data on infiltration tests support the conclusions.

Woodward-Clyde Consultants. 1985. *Phase I Engineering Services, Consolidated Environmental Projects, Rocky Flats Plant, Golden, Colorado*. Prepared for Merrick and Company.

This report summarizes the bedrock geology and hydrogeology of the RFP area. Detailed descriptions of the Arapahoe and Laramie Formations, Fox Hills Sandstone, Pierre Shale, Rocky Flats Alluvium, and the Eggleston Fault are included in the geologic discussion. The site hydrogeology is summarized, and the discussion includes the Arapahoe aquifer, Great Western Reservoir, South Platte River, and domestic irrigation wells in the area. Geologic and hydrogeological maps are included to visually aid discussion topics.

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Woodward-Clyde Consultants. 1992. *Environmental Restoration Technical Support Document (ERTSD), NEPA Support Document for the Rocky Flats Plant, Golden, CO.* Prepared for EG&G Rocky Flats, Inc. June.

The purpose of this ERTSD is to summarize environmental baseline data regarding RFP and its operable units (OUs). Groundwater information was summarized from several recent documents. The sitewide hydrologic systems as well as individual OU hydrologic systems are detailed. The summary includes historical descriptions of current and ongoing groundwater monitoring programs, the monitoring-well network, and a groundwater impact evaluation.

Woodward-Clyde Consultants. 1992. *Site Assessment for the Wind Site, Rocky Flats Plant.* Prepared for EG&G Rocky Flats, Inc. October 10.

In order to evaluate potential sources of contamination to potable water at the Wind Site, a site assessment was conducted utilizing sonic drilling. During 1989, volatile organic compounds (VOCs) were detected in tap water at Building 250. Potential sources of contamination include aboveground gasoline storage tanks in the vicinity, possible fuel spills near a water well, and possible surficial spills of various chemicals. The site hydrogeology is summarized, allowing for a better understanding of site conditions and possible groundwater/surface interactions. Monitoring wells were installed and sampled to evaluate the source of contamination. Boring logs, figures, and tables present data collected. Analytical data confirm that metals and VOCs are present in groundwater beneath the Wind Site indicating the potential for multiple, small sources west (upgradient) of the newly installed wells. Groundwater monitoring should be continued to evaluate the extent of contamination over time.

Zeff, Congorno, and Searly, Inc. 1974. *Report of Subsurface Studies for U.S. Atomic Energy Commission Sanitary Landfill Renovations, Rocky Flats Plant, Golden, Colorado.*

This report presents the results of field and laboratory investigations of subsoil conditions at the Sanitary Landfill conducted to evaluate proposed renovations at the site. Soil samples, collected from borings and test pits, were visually described in the field and laboratory tested for physical and mechanical properties. A study of the geologic and hydrologic setting, seismicity, slope stability, and subsurface conditions has been made. The site is classified as a Zone 1 seismic risk area. Groundwater flow occurs mainly above the

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bedrock surface with a secondary flow system through fractures in the claystone bedrock. Graphics of site location map, slope maps, cross-sections, and graphs of soil gradation analysis are included to support conclusions.

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- \*\*\* The Rocky Mountain Arsenal was constructed northeast of Denver, Colorado in 1942 for the manufacture of chemical warfare agents. Plant operations resulted in contamination of a shallow aquifer. Portions of the aquifer are currently being restored by barrier-treatment systems. Design of the final system required subsurface explorations to determine the amount and location of contaminated groundwater, and the configuration and characteristics of the alluvial aquifer. Subsurface explorations consisted of borings, aquifer pumping tests, and installation of monitor wells. Exploratory data were used to determine the location of the contaminant, to calculate the volume of contaminated water to be treated, volume of recirculated recharge water, and to construct a digital model for evaluation of the aquifer. Information obtained from the explorations was used to design the most economical and feasible containment/treatment system, which was a combined hydraulic-bentonite slurry barrier.

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- from NTIS database
  - from NISC database
  - from GEOREF database
  - from PLUS, Environ/Energyline database

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U.S. Geological Survey

Library  
Denver Federal Center  
2nd Avenue, Building 20  
Lakewood, Colorado

EG&G Rocky Flats, Inc.

Environmental Library  
Interlocken Business Center  
Broomfield, Colorado

Front Range Community College

Rocky Flats Reading Room  
Main Library  
3645 112th Avenue  
Westminster, Colorado

University of Colorado

Government Publications and Map Library  
Norlin Library  
Boulder, Colorado

Earth Sciences Library  
Geology Building, 2nd Floor  
Boulder, Colorado

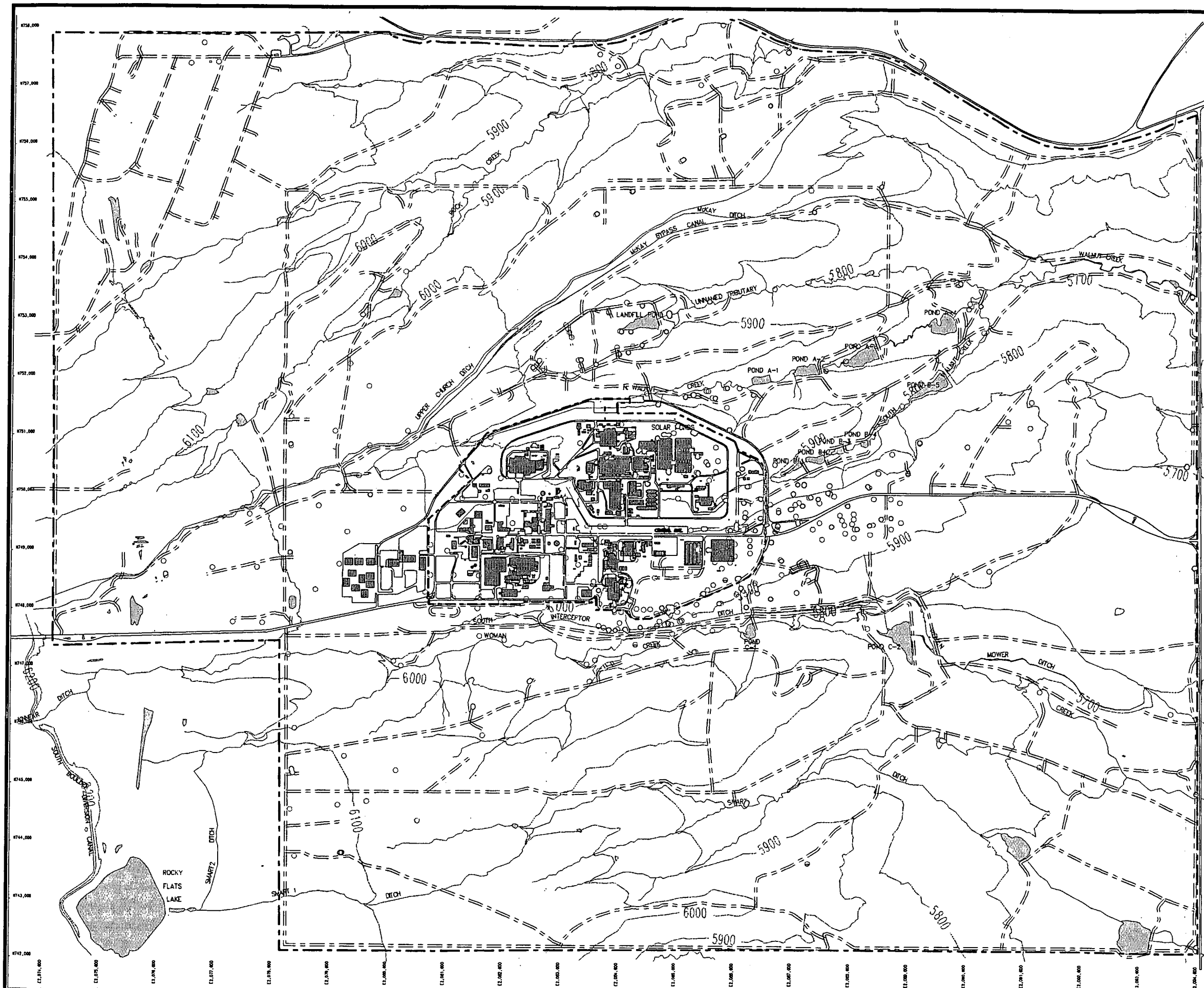
Colorado School of Mines

Arthur Lakes Library  
14th and Illinois  
Golden, Colorado

The S.M. Stoller Corporation

Environmental Services Library  
5700 Flatiron Parkway  
Boulder, Colorado

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# EXPLANATION

- Alluvial Wells
- ⊖ Alluvial/Bedrock Wells
- Bedrock Wells
- Buildings
- Surface Water Impoundment
- Paved Roads
- - - Dirt Roads
- Streams and Drainages
- - - Industrial Area
- - - Plant Boundary



Scale

0 feet 1700 3400

Topographic Contour

Contour Interval = 100 feet

**EG&G ROCKY FLATS**

Rocky Flats Plant, Golden, Colorado

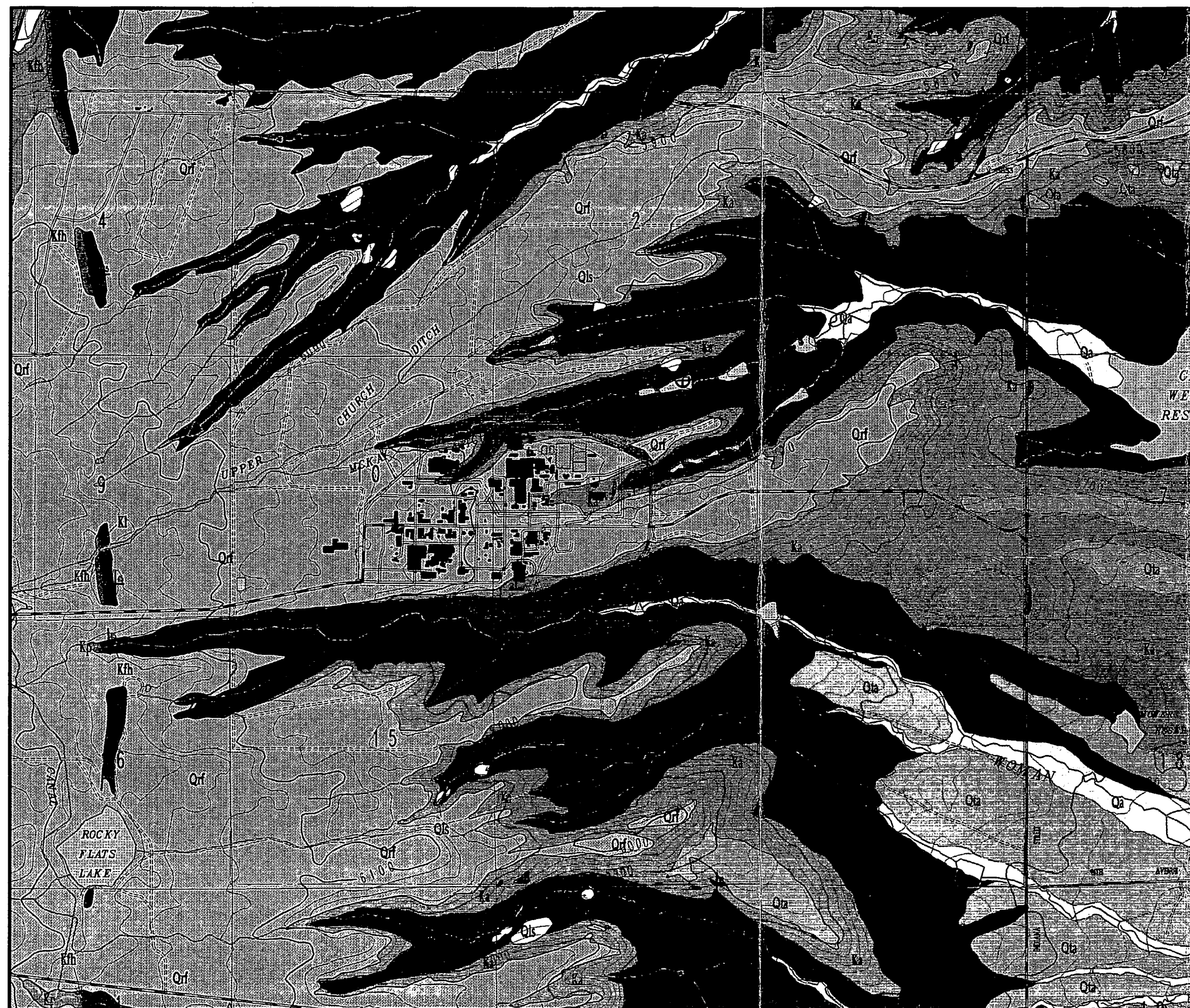
## Rocky Flats Plant Site

Groundwater Geochemistry of Rocky Flats Plant

Date: December 1993

Figure 1.0-2





# EXPLANATION

- Artificial Fill (RECENT)
- Valley Fill Alluvium (RECENT)
- Landslide Slump (RECENT)
- Undifferentiated Alluvium (PLEISTOCENE)
- Rocky Flats Alluvium (PLEISTOCENE)
- Arapahoe Formation (CRETACEOUS)
- Laramie Formation (CRETACEOUS)
- Fox Hills Sandstone (CRETACEOUS)
- Pierre Shale (CRETACEOUS)

Strike and dip of bedding planes in bedrock

- 50  
inclined
- vertical
- 20  
overturned
- horizontal

- Gravel, sand, or clay pit
- BM Benchmark

- Area of bedrock exposure

- Contact  
dashed where approximately located;  
dotted where concealed

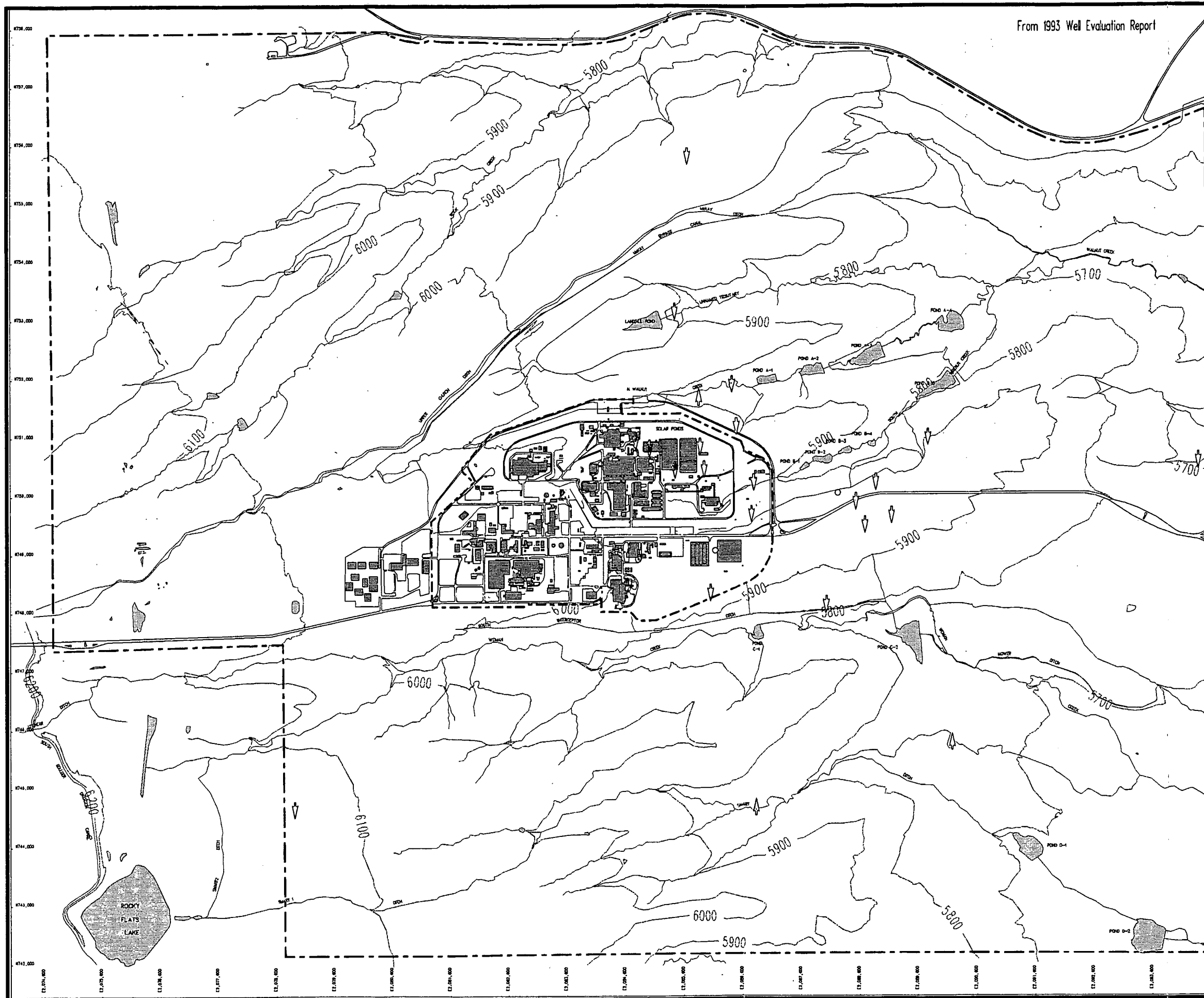
SCALE 1" = 2000'

2000' 0 2000'

**EG&G ROCKY FLATS**  
Rocky Flats Plant, Golden, Colorado  
**Geologic Map**  
of  
**Rocky Flats Plant**  
Groundwater Geochemistry of Rocky Flats Plant

Date: December 1993

Figure 13-1



## EXPLANATION

- Downward Vertical Gradient Between Depth-Discrete Screen Intervals
- Upward Vertical Gradient Between Depth-Discrete Screen Intervals
- No Apparent Vertical Gradient
- Buildings
- Surface Water Impoundment
- Paved Roads
- Streams and Drainages
- Industrial Area
- Plant Boundary



Scale

0 feet 1700 3400

Topographic Contour

Contour Interval = 100 feet

**EG&G ROCKY FLATS**

Rocky Flats Plant, Golden, Colorado

### Vertical Gradients Measured at Well Cluster Locations

Groundwater Geochemistry of Rocky Flats Plant

Date: December 1993

Figure 1.4-3